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The Radiant and Orbit of the Meteors of February 9, 1913

By C. C. WYLIE

The meteors of February 9, 1913, are among the best known of modern times, being mentioned in general textbooks, books on meteors and meteorites, encyclopedias, histories, and popular books. More than 140 reports are available,[1] nearly all having been collected and published by Professor C. A. Chant, of the University of Toronto. Had he not made that prompt investigation, this study would have been quite impossible.

The Popular Explanation is Untenable

The popular explanation of the phenomenon is that a cluster of fireballs travelled from Saskatchewan across North America, and over the Atlantic to the equator, a distance of some 5700 miles. Several considerations, of which we will mention four, make this explanation untenable.

First, the letters give the descriptions we would receive from intelligent people on a shower of meteors with a radiant in the north-northwest. They do not describe what the popular explanation assumes—a cluster of fireballs rising from behind objects on the horizon in the west-northwest, crossing the sky on a great circle, and going behind objects on the horizon in the east-southeast.

Second, the disappearance of a shadow-casting meteor behind objects on the horizon is impressive, and observers who see it comment on the spectacle when they write. The fact that no observer reports seeing this shows that few, if any, bright meteors went behind objects on the horizon for the more than 140 observers reporting. This, in turn, shows that the paths cannot have been especially long, for we have received such reports on several meteors.

Third, only shadow-casting meteors come low enough for detonations. The shooting stars coming from the same radiant must have ended twenty-five or thirty miles higher than the detonating meteor. Any conclusions based on the assumption that the shootings stars and the detonating meteor were at the same height when brightest must be erroneous.

Fourth, the kinetic energy of a meteor about as bright as the full

[1] *Journal of the Royal Astronomical Society of Canada*, Vol. 7, pp. 145-215, 383, 404-413, 438-447; Vol. 9, pp. 287-289; *Journal British Astronomical Association*, Vol. 24, pp. 101-111; Popular Astronomy, Vol. 30, pp. 632-637; Vol. 31, pp. 96-104, 443-449, 501-505.

moon, and travelling at a speed of seven miles per second at a height of about twenty-five miles, is sufficient to maintain that velocity against the air resistance for eight to ten miles. A drop in speed lessens the air resistance, but it also lessens the kinetic energy, and the meteor drops into denser air. When a meteor no brighter than the full moon has dropped to a speed of seven miles per second, and a height of twenty-five miles, the end of its path is very near.

The popular explanation has been quite generally accepted,[2] but Fisher and Hoffmeister[3] have questioned whether it is completely correct. Neither, however, appears to challenge the assumption of long paths extending from horizon to horizon and neither makes any determination of the radiant or a calculation of a real path.

The Fireballs of February 9, 1913

The following are the more important fireballs which probably fell from the leading radiant on that night:

First, a detonating meteor which fell over Ontario at 9:06½ P.M., 75th meridian time.

Second, a shadow-casting meteor observed from Ann Arbor, Michigan, at 10:15 P.M., C.S.T. (11:15 P.M., 75th meridian time).

Third, a spectacular fireball[4] observed from Bermuda at 10:00 P.M., Atlantic time (9:00 P.M., 75th meridian time).

Fourth, a shadow-casting meteor observed in Ontario at 1:25 A.M., 75th meridian time, February 10.

Fifth, a daylight detonating meteor which fell in Patagonia at 6:00 A.M., February 10.

In addition to these spectacular meteors, several groups of shooting stars were observed, among them the following:

Fort Frances, Ontario, 9:00 P.M., C.S.T. (10:00 P.M., 75th meridian time). A string of forty or so meteors, followed after five minutes by a string of eight, passed north of overhead.

Mortlach, Sask., 7:10 Mountain time (9:10 P.M., 75th meridian time). "Must have been hundreds."

Watchung, New Jersey. (Time not given, returning from church). Saw seven distinct meteors, two burst.

Pense, Sask., 7:00 M.S.T. (9:00 P.M., 75th meridian time). Considerable number of meteors seen singly and in groups.

Ontario. Shooting stars unusually bright, or in unusual numbers, were reported at various times from 7:30 P.M., February 9 to 2:20 A.M., February 10. The greatest number were noticed immediately after the fall of the detonating meteor, as people were looking up then. Only two or three were definitely not from the leading radiant.

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[2] Baker, *Astronomy*, (third edition), p. 249; *Encyclopaedia Britannica*, Vol. 15, p. 339; Fath, *Astronomy*, (third edition), p. 229; Hutchinson, *Splendour of the Heavens*, Vol. 1, p. 441; Jones, *Worlds Without End*, p. 139; Newcomb-Engelmann, *Populaire Astonomie, Siebente Auflage*, p. 515; Nininger, *Our Stone-Pelted Planet*, pp. 85-86; Olivier, *Meteors*, p. 242, Russell-Dugan-Stewart, *Astronomy*, Vol. 1, pp. 453-454; Waterfield, *A Hundred Years of Astronomy*, p. 481.

[3] Fisher, Popular Astronomy, Vol. 36, pp. 398-403; Hoffmeister, *Die Meteore*, p. 78.

[4] The report indicates that a single fireball, which burst, was observed in Bermuda.

Atlantic Ocean. Five ships reported meteors in unusual numbers, at times varying from 8:51 to 10:01 P.M., 75th meridian time. For one ship the shower continued thirty minutes. Three of the five ships reported the general direction of motion as follows: "from north to south," "from west by north to southeast," and "from west of the constellation Orion toward the south." These directions are all in general agreement with the leading radiant.

England. Bright meteors were unusually numerous according to Denning. No time or radiant is given.

The Apparent Radiant

To determine the apparent radiant the reports were examined to find those giving the apparent path of a meteor or fireball in the sky. Reports giving merely an estimate of the general altitude and direction of the path are of no value. Neither are the numerous reports giving the observer's guess as to the real direction of travel of the meteor. Two references suggest that the radiant was under the constellation Cassiopeia. One observer reports that a bright meteor appeared "right under Cassiopeia" and travelled northward. Another reports that the meteors came from 5° west of Cassiopeia and travelled southward.

Three reports were selected as of value in determining the apparent radiant. First, an astronomer at the University of Michigan gives the right ascension and declination of the points of appearance and disappearance of the Ann Arbor meteor, a shadow-casting fireball. Second, Colonel Winters, who observed a fireball in Bermuda, reported that it appeared in Ursa Major and went across the eastern sky. A measured altitude of 30½° is given as its apparent height in the eastern sky. Unfortunately, the azimuth of this point is not given, but as the altitude changes rather slowly, the error in assuming a due east direction probably is not great. Third, an observer at Dunnville, Ontario, reported that meteors passing exactly overhead were travelling in a due east-southeast direction. For overhead meteors the apparent direction of travel is the real direction, and so this report can be used. Probably these are the only reports from which one could hope to determine the radiant directly with an uncertainty of less than 20°.

Using these three reports the apparent radiant was determined as, approximately, in right ascension $= 21^h\ 30^m$, declination $= +61°$. It is interesting to note that a detonating meteor which fell in Europe on January 25, 1894, had an apparent radiant in right ascension $= 22^h\ 1^m$, and declination $= +55°$. In this preliminary determination of the radiant,[5] the zenith attraction has not been allowed for, and the error due to that might be more than 10°.

The radiant can be determined more accurately by computing the path and apparent radiant of the detonating meteor and then obtaining the zenith attraction on the assumption that the Ann Arbor fireball, reported

[5] From the more accurate work of the following paragraphs, the apparent radiant of the Ann Arbor meteor was determined as R. A. $= 21^h25^m$, Decl. $= +60°\ 43'$. The agreement with the approximate determination is excellent.

by the University of Michigan astronomer, came from the same radiant and with the same velocity. The 140 reports collected by Professor Chant are sufficient for a reasonably good path of the detonating meteor, but the report of the astronomer is the only one giving the coördinates for even a single meteor.

The Projected Path of the Detonating Meteor

To determine the projected path, let us consider the Ontario reports stating that the meteor (or meteors) passed to the one side or the other of the zenith. We find the following:

Berlin — east
Brampton — little west of point overhead
Caledon East — toward Orion (southwest)
Campbellville — *directly* overhead
Dunnville — directly overhead (one report), 10° southwest of zenith (other report)
Elora — right overhead
Georgetown — little to west
Guelph — slightly to northeast of zenith
Hespeler — overhead, or little to north
Jackson — nearly overhead but a little to the southeast (*i.e.*, east rather than west)
Mt. Charles — directly overhead
Sheridan — southwest
Toronto — southwest, or west
Waterloo — east.

For many of these, the report indicates that the detonating meteor was seen. It is a safe assumption that it was seen by most of the others, as its light would have caused most persons outdoors to look up. Such persons would notice the shooting stars in the same general region as the path of the detonating meteor, and very few others would notice any shooting stars. We can assume that in nearly all cases, the reported direction from the zenith is that of the detonating meteor.

A projected path was drawn[6] passing a little east of Jackson and exactly over Campbellville, in perfect agreement with those reports and in general agreement with all others given above except Dunnville. The Dunnville reports are brief, and one of them is "second-hand." There is nothing in either report to indicate that the detonating meteor was seen by the observer. Reports from other communities indicate that the detonating meteor did not go as far south and east as Dunnville. Presumably the Dunnville reports refer to smaller meteors which passed through, or near, the zenith.

[6] The direction in which an observer guesses a meteor is travelling cannot be used in drawing the projected path unless the meteor passes practically overhead. The Campbellville observer saw the meteor directly overhead, but he gives only the general direction "northwest to southeast." There is only one apparently careful estimate of direction from overhead meteors, the Dunnville report, which we used in determining the approximate position of the apparent radiant. The azimuth of the adopted path is in good agreement with this report.

The Real Height of the Detonating Meteor

We have two measurements on the apparent height of the detonating meteor. This is good for that number of reports, and it is enough to fix the real height of the path. The first measurement is from Mill Bridge. As Mr. Norman stepped out of a door at the southeast corner of his barn, the bright meteor flashed past the eaves of the roof on the southwest corner. Mr. Norman measured 20 feet from his head to the eaves and 50 feet to a point under the eaves, so the altitude of the meteor must have been the angle whose tangent is 20/50, or 22°. In our calculation, we assume that Mr. Norman did not see the meteor instantly but that the head of the meteor was 5° to the south of due west when he saw it on a level with the eaves of his barn.

The other measurement is from Springville. Rev. D. B. Marsh noticed that the head of the large meteor was eclipsed by the top of a telephone pole. He set up a transit instrument where he had been standing, and measured the azimuth as 49°, and the altitude as 14° 58′. The measurements determine the real height of the meteor above the projected path at each of the two points, and consequently the real height at all points.

The Point of Appearance

In fixing the points of appearance and disappearance, one must keep in mind that most of the directions refer to the apparent direction of travel rather than to the points of appearance and disappearance, that many of the reports are on the fainter meteors rather than on the detonating meteor, and that there is a psychological tendency to lengthen the path. We selected the reports on the detonating meteor which appeared to fix the direction with the greatest care, and obtained for the point of appearance the following:

Bolton — a little west of northwest
Melrose — west or slightly north of west
Toronto — 34° west of north (but states he did not see the beginning because of a building)

To these we can add the Jackson report, that the meteor was first seen in the northern sky. We have adopted a point a short distance northeast of Jackson and at a height of 67 miles above the projected path as the point of appearance.

For most spectacular meteors the point of bursting, or disappearance, is fixed much better than the point of appearance. The meteor appears unexpectedly, and when an observer looks up his eyes follow the meteor in its motion across the sky. When it disappears, there is nothing to distract his attention and that point is remembered rather well. The Ontario detonating meteor, however, was an exception. About the time it disappeared the attention of observers was distracted by the smaller meteors coming into view. A very small number report the direction of the big meteor at the time of its disappearance. Several comment on the bursting, but without giving the direction more definitely than "nearing the southeast," for example.

We have selected the following three reports to fix the point of disappearance, which must, of course, lie on the projected path.

Edgar — nearly due south
Falkenburg — south southwest
Campbellville — when half-way to the horizon

From these we adopted a preliminary point about ten miles north, and a little east, of Dunnville, at a height of 17 miles. We deliberately carried the path farther south and east than the reports indicated, to show how the error could be corrected and the endpoint fixed more accurately from the reports on detonations.

The Endpoint from Detonations

We assumed 995 feet per second as the velocity of sound. This corresponds to an average temperature of approximately —50° F. On calculating the interval which should have been required for detonations to reach the persons in the various communities we found that for the great majority of observers who reported a time interval, the interval was too great. The result shows a systematic tendency to overestimate the duration of the display. Perhaps the unusually slow motion of the meteors was responsible.

The greatest discordance was for Toronto where the time for the detonating meteor was given as 9:05 and the time for hearing the detonations was given as 9:12. This is an interval of seven minutes whereas a computation of the approximate travel time for the detonations gave $3^m\ 28^s$. Closer examination of the times for the detonating meteor shows that persons who report looking at a watch give the following 9:04½, 9:05, 9:06, and 9:08.

For the 9:06 and 9:08 times it is stated that the watch usually is correct within a few seconds. No such statement is made for the 9:04½ and 9:05 times, so those should be given less weight. Another consideration is that persons who saw the meteor were outdoors, in general in dark surroundings. No doubt the watch was looked at some time after the fall of the meteor, and an allowance made for the estimated time interval since. This interval was overestimated more than underestimated, as we have said, which would make the watch time, as given, too early. From these considerations we have adopted 9:06½ as the time of fall.

The reports from Toronto show that many persons heard two rolls of thunder separated by an interval of about two minutes, or the time in which one man walked two short blocks on that cold winter night. The time 9:12, which is given twice, refers to the second roll of thunder in both cases. What this second roll of thunder was we cannot say. It was not so loud as the first report, which did come from the meteor. There is a reference to Humber Bay and another reference, not from Toronto, to the thunder sounding like ice cracking. Perhaps, this second roll of thunder was due to ice cracking in the bay; or it may have been an echo of the detonations of the meteor. The wind velocity in

Toronto at that time was 24 miles per hour, which presumably is sufficient to crack ice.

The reports indicate, as we have said, that the first detonations reached Toronto about two minutes before 9:12. This means that they arrived at about 9:10. We now have the discrepancy in the Toronto times removed, for from the fall of the detonating meteor, 9:06½, to the arrival of the first detonations, 9:10, is 3½ minutes, agreeing with the calculated travel time of $3^m 28^s$.

For a considerable number of communities we are told whether the detonations arrived during, or after, the display of shooting stars which followed the fall of the detonating meteor. The following are some of these communities, together with the travel time for the detonations computed from the path of the meteor as drawn.

Place	Travel Time	Detonations Heard
	m s	
Sheridan	2 50	During display
Georgetown	3 01	Few seconds after
Springbrooke	3 04	During display
Brampton	3 15	After display
Hespeler	3 19	After display
Mt. Charles	3 22	After display
Toronto	3 28	After display

The Springbrooke and Georgetown reports indicate that the noticeable display continued for about three minutes after the fall of the detonating meteor. There was a small discrepancy in that the Georgetown report indicates the display was ended $3^m 01^s$ after the fall of the detonating meteor, while the Springbrooke report indicates it was continuing $3^m 04^s$ after the fall of the detonating meteor. As one observer can watch only a small part of the sky, it is quite possible that the last meteor (or group) seen by the Springbrooke observer was missed by the Georgetown observer. However, our data on the detonating meteor, on air conditions, and on the location of observers are not accurate enough to justify any concern over such a small discrepancy.

There was a real discrepancy, however, in the reports from Cayuga, Dunnville, and St. Davids. The thunder was heard after the close of the display at all of these places while, according to our preliminary path, it should have reached Dunnville $2^m 03^s$ after the fall of the detonating meteor, or well before the close. This indicated that our preliminary path was carried too far to the south and east.

To remove this discrepancy, the adopted bursting point was moved back along the path to a height of 25 miles over a point about eight miles east of Hamilton. This gives a travel time for the detonations of $3^m 26^s$ for Dunnville, of $3^m 8^s$ for Cayuga, and of $3^m 52^s$ for St. Davids. This adopted endpoint agrees better than the preliminary with the directions reported for the detonations,—from the north for Cayuga, the direction of Hamilton for Canfield, and from the west for St. Davids. It also agrees better than the preliminary with the reports on the point of dis-

appearance from Edgar, Falkenburg, and Campbellville, as given previously.

The only real discrepancy remaining, in either time or direction in the reports on detonations, is from Oakville. The observer reports that the detonations came from the north, whereas the shock wave should have reached him from the southwest. Probably this observer was standing in the "sound shadow" of some building, or was indoors, so that an echo coming from the north was the first loud sound to reach him.

Wind Direction from the Detonations

The dotted line on the accompanying map encloses the area within which practically all observers reported detonations, and outside of which only one reported detonations, an observer from Edgar. This is indicated by the small dotted circle north of the main area. There is a possibility that the noise heard at Edgar was not from the meteor, as a

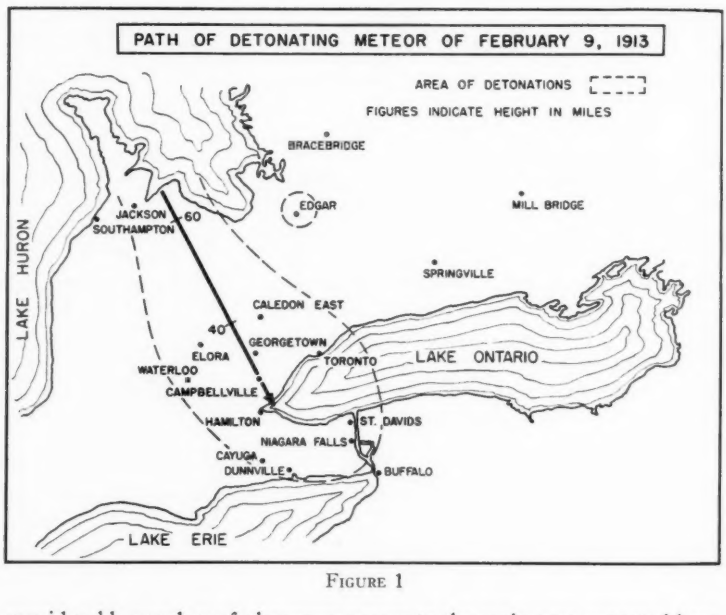

Figure 1

considerable number of observers nearer to the main area reported hearing no sound, and the detonations were not heard by the observer at Edgar who sent in the report. However, it is possible that the person who heard the roll of thunder was in open country, and in exceptionally favorable surroundings for hearing relatively faint detonations.

A casual inspection of the area within which the detonations attracted general attention shows that it is not symmetrical. It is distinctly to the east and south of the path of the meteor. Edgar is to the east of that

area so if that observer heard real detonations the lack of symmetry is even more pronounced. This suggested that at the time of the fall of the meteor, northwesterly winds were prevailing over that part of Ontario. We, therefore, wrote to Mr. J. Patterson, Controller of the Meteorological Division of the Air Services at Toronto, Canada. Mr. Patterson replied that "at 8:00 P.M., a cold wave was advancing rapidly from northwestern Ontario with westerly winds." At 9:00 P.M. the winds were north and northwest, in general, for the area of detonations. This accounts for the area lying farther to the east and south than is normal for a detonating meteor.

Preliminary Determination of the Velocity

Estimates for the duration of the detonating meteor ran from a few seconds up to three minutes. No doubt the higher estimates were due to the observer's confusing the duration of the entire display with the duration of the detonating meteor. From celestial mechanics, the minimum velocity with which a meteor can enter the earth's atmosphere is seven miles per second. The path length was 116 miles, so even making allowance for atmospheric retardation, the duration could hardly have exceeded 20 seconds. Estimates of 30 seconds and above were rejected as impossible. Using the nine lower estimates which appeared to refer to the detonating meteor, we obtained $12\frac{1}{2}$ seconds for the duration, corresponding to a velocity of 9.3 miles per second. This was only a preliminary figure, and it was rounded off to $9\frac{1}{2}$ miles for obtaining the more exact value of the velocity from the zenith attraction.

The Velocity from the Zenith Attraction

It was assumed that the meteor reported from Ann Arbor came from the same radiant and with the same velocity as the Ontario detonating meteor. The procedure for obtaining the accurate velocity was as follows: With the preliminary value for the velocity (9.5 miles per second), the altitude of the radiant of the detonating meteor was corrected for zenith attraction. The corrected radiant was reduced to right ascension and declination. The right ascension and declination of the corrected radiant were reduced to altitude and azimuth for Ann Arbor at the time of the fall of the Ann Arbor meteor. With the preliminary value of the velocity, the zenith attraction was computed, and the altitude and azimuth of the apparent radiant were obtained for Ann Arbor. These coördinates of the apparent radiant were reduced to right ascension and declination, and checked against the great circle of the Ann Arbor meteor. If the correct velocity had been assumed, the radiant of the detonating meteor would seem to fall on the great circle of the Ann Arbor meteor as seen from Ann Arbor.

The work was carried through graphically for the assumed velocity, 9.5 miles per second, and it was found that the radiant missed the great circle by some two degrees. The graphical work indicated that the correct velocity was about 10.2. Computation using a slide rule and four-place

logarithms indicated that this should be adjusted to 10.1 miles per second, which value was adopted. This method of determining the velocity from the zenith attraction is reasonably accurate for velocities and radiants as low as this.

We can now assemble the results on the detonating meteor in tabular form:

Time of fall	(75th meridian) 1913, February 9, 9:06½ P.M.
Longitude of appearance	80° 48′ West
Latitude of appearance	44° 41′ North
Height of appearance	67 miles
Longitude of bursting	79° 46′
Latitude of bursting	43° 23′
Height of bursting	25 miles
Length of path	116 miles
Projected length	109 miles
Apparent velocity	10.1 miles
Geocentric velocity	7.33 miles
Heliocentric velocity	21.11 miles
Azimuth apparent radiant	151° from south
Altitude apparent radiant	20°
R.A. apparent radiant	327° 15′
Decl. apparent radiant	+56° 40′
Altitude corrected radiant	7° 18′
R.A. corrected radiant	315° 15′
Decl. corrected radiant	+46° 16′
R.A. heliocentric radiant	32° 0′
Decl. heliocentric radiant	+31° 22′

Comparison with Reports of Observers

The Ontario reports are typical in that most give what the observers thought was the direction of travel, rather than the directions of appearance and disappearance. For some, fictitious lengthing along an almucantar of altitude is very great. Making due allowance for these psychological errors, however, the agreement of the computed path with the reports is very good.

The adopted radiant and velocity fit the Ann Arbor report perfectly since that was used in deriving them. A graphical check showed good agreement with the Bermuda fireball, and satisfactory agreement with the rather indefinite reports on the second Ontario fireball, the fireball from Patagonia, and the showers referred to earlier in this paper as reported from Canada, the United States, and the Atlantic Ocean. No doubt, nearly all the meteors reported on that night were from the same shower, and the radiant and velocity must have been very close to that which we have adopted. While the path of this detonating meteor cannot be considered as well determined as those from modern measures, the reports are so numerous and complete that we believe it is determined much better than most paths based on the older observations.

The Orbit

From the heliocentric radiant and velocity the orbit about the sun was computed. The orbit is direct, and it resembles the orbits of the small asteroids which come close to the earth, rather than those of comets.

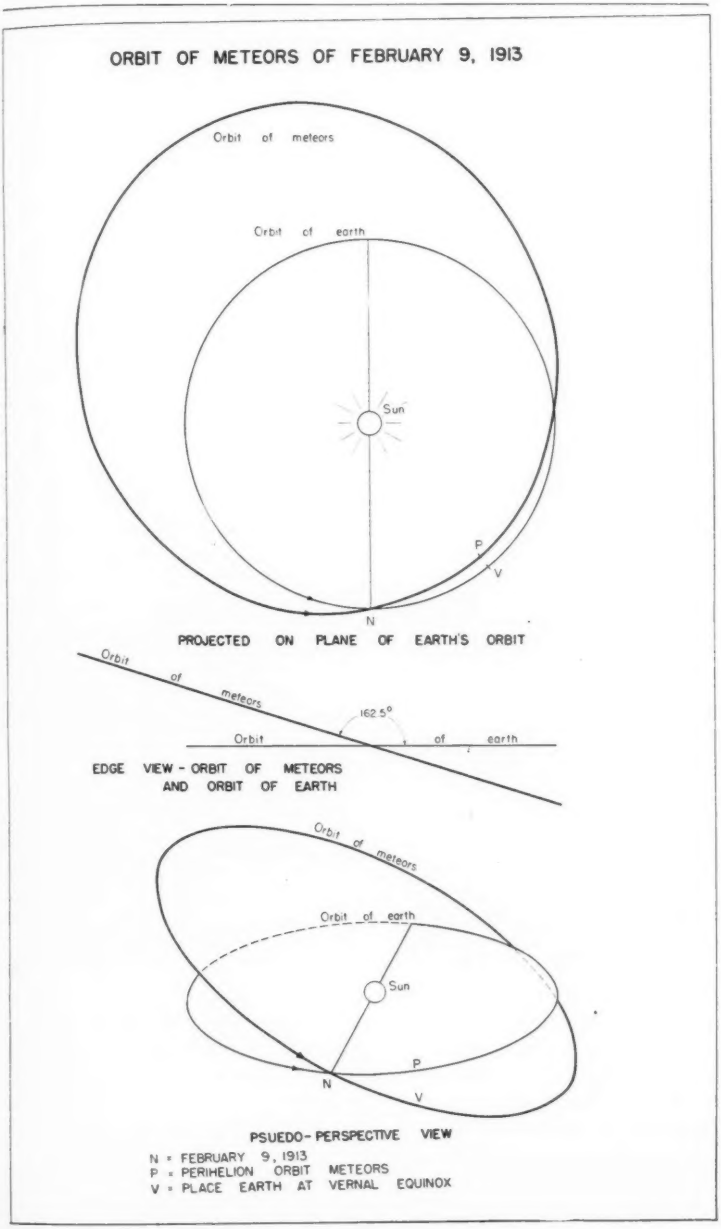
ORBIT OF METEORS OF FEBRUARY 9, 1913
Orbit of meteors
Orbit of earth
Sun
P
V
N
PROJECTED ON PLANE OF EARTH'S ORBIT
Orbit of meteors
162.5°
Orbit of earth
EDGE VIEW - ORBIT OF METEORS AND ORBIT OF EARTH
Orbit of meteors
Orbit of earth
Sun
P
N
V
PSUEDO-PERSPECTIVE VIEW
N = FEBRUARY 9, 1913
P = PERIHELION ORBIT METEORS
V = PLACE EARTH AT VERNAL EQUINOX

FIGURE 2

However, the shower of shooting stars in connection with this fall indicates a swarm of small particles which is characteristic of comets rather than asteroids. The following are the elements obtained.

$$
\begin{aligned}
a &= 1.38 \\
e &= 0.328 \\
\omega &= 220^\circ.3 \\
\Omega &= 320^\circ.8 \\
i &= 17^\circ.5 \\
P &= 1.62 \text{ years}
\end{aligned}
$$

Summary

The meteoric display of February 9, 1913, was a shower of fireballs and shooting stars from a radiant in the north-northwest. It was not a procession of fireballs moving over an unusually long path. The most spectacular meteor of the display was a detonating meteor which fell in Ontario at 9:06½ P.M., 75th meridian time.

The approximate radiant is indicated by three references to Cassiopeia, and it was computed from the paths of the Ann Arbor and Bermuda fireballs, together with the direction of travel of overhead meteors in Ontario.

The true geocentric radiant was computed from the detonating meteor, and the Ann Arbor meteor observed by an astronomer, as follows: the projected path of the detonating meteor was drawn using reports which gave the direction of the path from overhead. The height of the real path at various points was obtained from two measurements of the apparent height. The directions of the points of appearance and disappearance were obtained by selecting the reports which appeared to give these directions the most carefully. The endpoint was obtained more accurately from the detonations as follows: without using any estimates of time this point was made to agree with the reports stating whether the detonations occurred during or after the display of shooting stars. The approximate velocity was obtained from the estimates of duration. An accurate value for the velocity was obtained on the assumption that the Ann Arbor meteor came from the same radiant and with the same velocity as the detonating meteor. With this value of the velocity, the altitude of the apparent radiant was corrected for zenith attraction and the right ascension and declination of the true radiant were obtained.

From the right ascension and declination of the radiant and the apparent velocity, the geocentric velocity and the heliocentric velocity were computed. The right ascension and declination of the heliocentric radiant were computed, and, following this, the elements of the orbit about the sun. The orbit is direct, and it resembles the orbits of the small asteroids which pass inside the orbit of the earth rather than the orbits of the comets.

University of Iowa, April 27, 1939

A Vacuum Chamber for Aluminizing the 82-Inch Mirror of the McDonald Observatory

By ROBLEY C. WILLIAMS

Shortly after the signing of the contract for the McDonald Observatory by The Warner & Swasey Company in 1933, the late Mr. E. P. Burrell, Director of Engineering of the firm, became greatly interested in constructing a vacuum chamber in which the 82-inch mirror for this observatory could be coated with an evaporated film. Mr. Burrell was largely responsible for the final design of the equipment, although its construction was not completed until some time after his death in 1936. The general notions underlying the design and construction of the

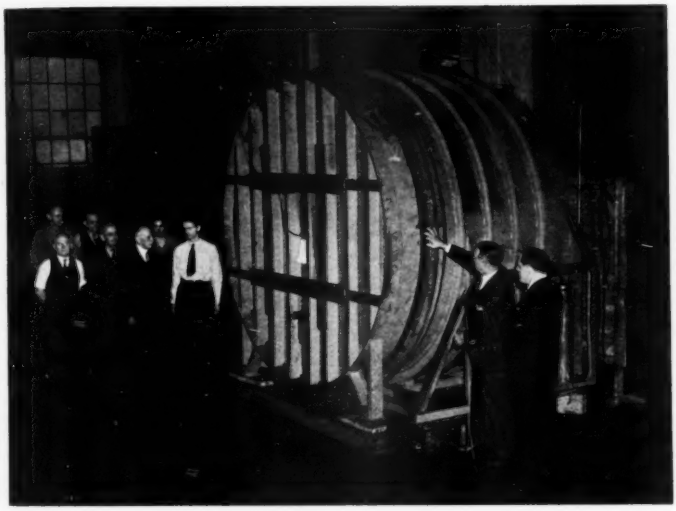

FIGURE 1
A GENERAL VIEW OF THE 109-INCH VACUUM CHAMBER WITH THE LID BOLTED IN PLACE.

chamber were that it should be made extremely rigid, that it should be constructed to allow the insertion of practically any shape and size of mirror, and that it should be large enough to accommodate all the existing and proposed mirrors, with the exception of the two giants in California. The cell construction was completed in the spring of 1938, and its operation was considered satisfactory a few months later. Since the summer of 1938 a number of mirrors have been coated in the chamber,

including a 30-inch spherical and 60-inch flat used in the Warner & Swasey shop, and a 28½-inch convex, a 21½-inch convex, and an 82-inch parabolic for the McDonald Observatory. All of these mirrors, of course, were figured under the able direction of Mr. C. A. R. Lundin.

The general size and shape of the vacuum chamber are best shown in Figure 1, where the cover is in place and the evacuation of the air has started. The internal diameter is 109 inches and the depth is 71 inches, resulting in a volume of 390 cubic feet or slightly over 11,000 liters. At the present time this is the largest vacuum chamber in existence operating for the purpose of coating mirrors, but will doubtless be exceeded in volume by the chamber to be used for coating the 200-inch mirror.

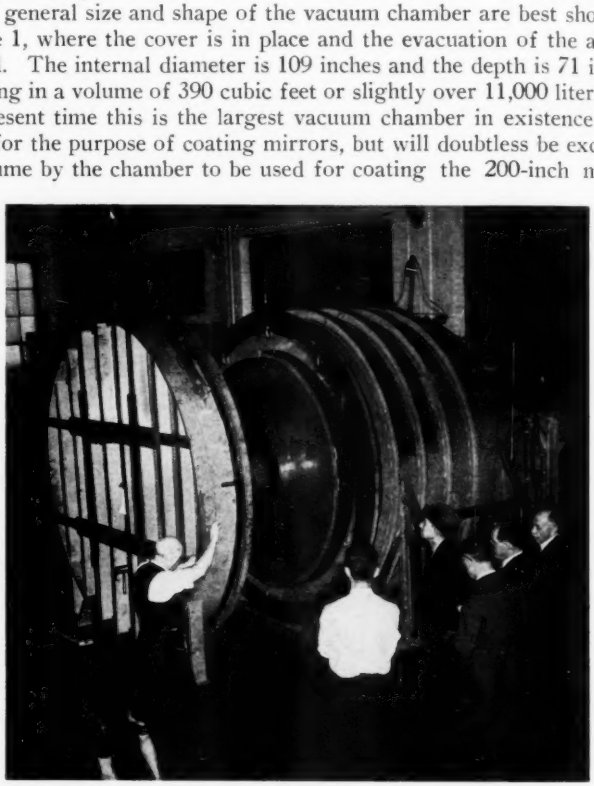

FIGURE 2
THE 82-INCH MIRROR OF THE MCDONALD OBSERVATORY SUSPENDED IN THE VACUUM CELL PRIOR TO ALUMINIZING.

The cylindrical part of the chamber is made of one sheet of selected boiler-plate, ⅜ inch in thickness, and electric welded in one seam. The necessary bracing is accomplished by four 4-inch I-beams bent into circular form and intermittent-welded to the outside of the cylinder. The end walls of the chamber, one of which is a removable cover, are also made of ⅜-inch sheet and strengthened by I-beams. It is a tribute to the Wellman Engineering Works of Cleveland that not a single leak was found in the 100 or so linear feet of welding necessary in the fabrication.

Figure 2 shows the lid of the chamber removed and supported by the crane, and also shows the 82-inch mirror hung in position for coating. The seal between the lid and chamber is obtained by use of a rubber gasket, the gasket fitting into a groove in the flange of the chamber, and the flange of the lid being shaped to a tongue to fit into this groove. Dimensions are so calculated that the shoulders of the flange come together after the rubber has been compressed and deformed 25%. Although some 24 holes are provided in the chamber flange for the bolting on of the lid, it is found that four bolts will safely hold it, and that these may be released as soon as the pump has started. The compressional force of the atmosphere on the lid is over 140,000 pounds, and the *lifting force* on the chamber as a whole is over 33 pounds when it is evacuated. Since the chamber weighs over 7½ tons, however, it has not been necessary to anchor it to the floor!

The 24 brass posts for the filaments are inserted through the fixed end of the chamber, and are mounted upon Isolantite insulators. The seal between insulator, post, and chamber is made on the outside of the chamber with Apiezon Wax. The filaments are mounted upon a circle whose radius equals the distance from the plane of the filament assembly to the plane of the mirror. This mounting follows directly the excellent suggestion of Dr. John Strong[1] of the California Institute of Technology. It results in a strikingly uniform deposit of metal, if the filaments are equally loaded, as is proven by the optical tests made before and after the coating of the 82-inch mirror.[2] The results of these tests indicate that the figure of the mirror was at least as excellent after the coating as before.

The pumping system consists of a Kinney Pump (VSD 8X 8) for the rough vacuum, and a pair of 6-inch oil diffusion pumps for the high vacuum. While the Kinney pump will not produce as low a pressure as, say, a Cenco Hypervac, it is many times as fast, and exhausts the air in the Warner & Swasey 109-inch vacuum chamber to a pressure of 0.01 mm of Hg in about three hours. The speed of the Kinney pump is indicated by the fact that 8 hours were required for two Hypervacs in parallel to exhaust, to the same pressure, Dr. Strong's 108-inch chamber,[3] which has about half the volume of the 109-inch chamber here described. After the oil diffusion pumps are started, about three hours are required for the pressure to reach that necessary for aluminizing. During the three hours a 1 kw., high-voltage discharge is maintained, in accordance with the technique developed for the aluminizing process by Strong.[4] This discharge is most efficacious in "cleaning up" the adsorped gases from the chamber walls and the surfaces of the mirror. The walls of the vacuum chamber were burnished with a polishing

[1] *P. A. S. P.*, **46**, 18, 1934.
[2] J. S. Plaskett, *Ap. J.* **89**, 84, 1939.
[3] *Ap. J.*, **83**, 401, 1936.
[4] *R. S. I.*, **6**, 97, 1935.

wheel by the fabricators, and the welds were carefully smoothed, so that no preparation of the walls beyond thorough cleaning was required. Three operations of the new chamber were performed before its walls were properly conditioned to allow a hard and brilliant film to be deposited.

The only vacuum gauge used is a Pirani Gauge, mounted in the high vacuum chamber itself. This type of gauge is usually mounted in the low-vacuum side, but its use in the high-vacuum side is entirely satisfactory. It is particularly valuable in locating leaks with the aid of alcohol, and in giving a continuous record of the excellence of the vacuum while the filaments are being operated. Another, and reliable, vacuum indicator is the high-voltage transformer, which, in experienced hands, gives dependable indications for pressures higher than about 5×10^{-5} mm of Hg.

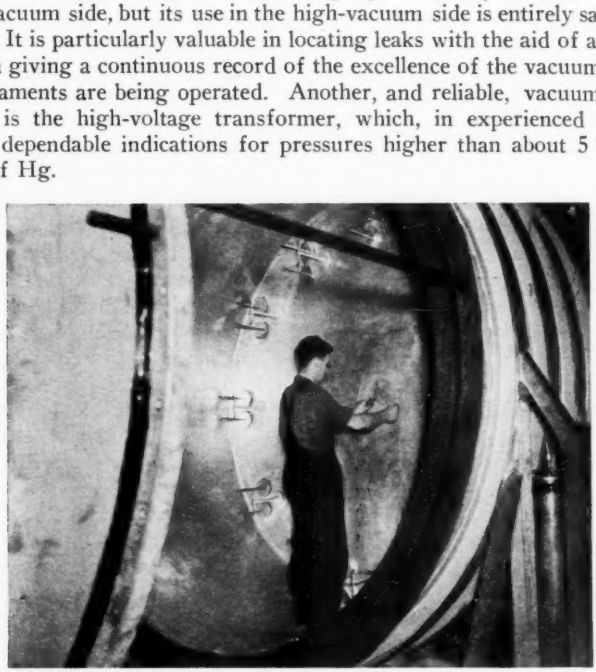

FIGURE 3

A CLOSEUP VIEW OF THE INTERIOR OF THE 109-INCH CHAMBER, SHOWING FILAMENT ASSEMBLIES AND BOMBARDING ELECTRODE.

Twelve filaments to be loaded with aluminum wire and twelve to be loaded with chromium lumps are provided, so that there can be deposited coatings of either metal singly or both in succession. So far in the operation of the cell only double films of aluminum over chromium[5] have been made, and in these the aluminum layer is about three times as thick as the chromium layer. The total film is just opaque to sunlight, which seems to be the generally favored thickness. Great care has to be taken in the heating of the first few filaments in order that the "out-

[5] R. C. Williams, *Phys. Rev.*, **46**, 146, 1934.

gassing" effect of the evaporating metal will not seriously increase the pressure, despite the rapid action of the pumps. Figure 3 shows a close-up of the interior of the chamber, and a few pairs of filament assemblies can be seen. The technician in the chamber is shown adjusting the high-voltage electrode.

The cleaning and coating of a large mirror has been fully described in the article by Dr. John Strong.[6] The process of cleaning used by the present writer is different mainly in that absolute ethyl alcohol is used as the final rinsing agent, and clean cheese-cloth is used for the final dry rubbing. The handling of the mirror itself is made very simple by the facilities of the Warner & Swasey shops. The 82-inch mirror is provided with a peripheral groove, and into and around this groove fits a steel ring. The ring is provided with two pairs of threaded holes, one diametral pair for the rods of the lifting yoke, and one off-center pair

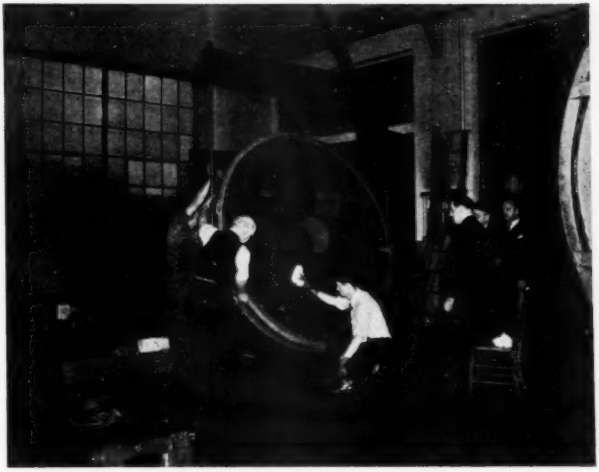

FIGURE 4

THE AUTHOR IS SHOWN REMOVING THE LAST BIT OF LINT FROM THE SURFACE OF THE 82-INCH MIRROR.

for the rods that fasten into the brackets on the flange of the chamber. The use of the ring and the first pair of holes is shown in Figure 4, in which the mirror is seen supported by the yoke from the overhead crane while the last bit of lint is removed. In Figure 2 the mirror is shown hanging in position to be coated in the chamber, and in this position the other pair of holes are in use. By this convenient method of handling, the mirror can be placed in the chamber or removed from it in about five minutes.

[6] *Ap. J.*, **83**, 401, 1936.

The time taken to reduce the pressure in the chamber to that sufficient for aluminizing is about six hours, but ordinarily pumping is continued for another five or six hours to let the pumping oil become thoroughly out-gassed. The filaments are operated two at a time, and the time taken for the actual evaporation is a little less than an hour. Small glass windows are provided in the cover so that the process may be observed. The last few filaments cannot be seen, of course, since by then the mirror surface is too opaque to be seen through. The pumps are allowed to cool for a few minutes after the coating process is finished, and then the air is re-admitted through a stop-cock with a ½-inch opening located behind the back of the mirror. It takes about 90 minutes for the air pressure to come to normal within the cell.

The 82-inch mirror for the McDonald Observatory was "chroluminized" for the first time on October 23, 1938. Following this, it was used in the optical shop for testing the convex secondary mirrors until the middle of February. At this time it was decided to recoat it, inasmuch as the first coating exhibited some signs of inadequate cleaning of the glass surface. Hydrochloric acid was used in concentrated form for removing the coating of aluminum and chromium, and the time taken for removal was about ten minutes. The mirror was recoated with chromium and aluminum on February 16, 1939, with completely satisfactory results. A "tent" of Cellophane braced with Scotch Tape was placed over the mirror to protect it from dust, and the completely boxed mirror, weighing 7300 pounds, was shipped on February 18 to Mt. Locke, Texas.

Giacobinid Meteors in 1939 and 1940?

By FLETCHER WATSON

On October 9, 1933, when the earth passed through the region occupied eighty days previously by the faint, short-period comet Giacobini-Zinner, the strongest meteor shower of this century appeared for a few hours. Since the period of the comet is about 6.6 years, it will pass the descending node of its orbit again early in 1940—on February 23, on the basis of the perturbed orbit (*Handbook Brit. Astr. Ass'n.*, 1939, p. 33). In 1939 the earth will precede the comet to the nodal point by 136 days, and in 1940 follow it by 229 days. It therefore appears probable that some recurrence of the Giacobinid meteor shower may be expected in either or both of these years. Any attempt, however, to predict the intensity of the shower in 1939 or 1940 would be unwise.

In 1933 the shower maximum occurred at 20^h G.C.T., October 9, when the longitude of the earth was 16°.07, or a tenth of a day later than expected from the longitude of the comet's node, 15°.97. In 1939 the earth reaches longitude 16°.07 at 3^h G.C.T., October 10, and in 1940 at 13^h G.C.T., October 9. The uncertainties resulting from perturbations

do not allow much weight to be assigned to these predictions of shower maximum, but the variations in the positions of the descending node (Table I) require that observers over the whole earth be alert. The

TABLE I

ORBITAL CHANGES OF COMET GIACOBINI-ZINNER

	Long. Desc. Node	Perihelion Distance
1900 III	16°.72	0.9319 A.U.
1913 V	15.87	.9759
1926 VI	15.94	.9937
1933 III	15.97	.9997
1940 (pred.)	15.97	.9964

radiant (at approximately R.A. $17^h\ 30^m$, Decl. $+55°$) will be on the meridian near $16^h\ 20^m$ local mean time. The moon (age 25 days) will not interfere with observation in 1939, but in 1940 (age 8 days) it will illuminate the evening sky.

In 1946 the comet will be due at the descending node of its orbit on or about October 1 and the earth will reach the same position only some eight days later. Although we may anticipate a shower of spectacular intensity (lunar age 19 days and therefore rising late), we must recognize the possibility that perturbations may divert the particles from collision with the earth's atmosphere. The wide-spread disappointment of astronomers and public alike, when the much heralded Leonid shower of 1899 failed to materialize, hindered the progress of meteoric astronomy for several decades. This unfortunate experience should serve as ample warning against any dogmatic predictions for 1946.

An attempt to analyze the heterogeneous records of the Bielid showers of 1872 and 1885 has made me aware that essential information not recorded on such occasions is lost forever. Therefore, to aid observers who hope to make valuable records of future intense meteor showers, the following suggestions are made. The observations may bear on two distinct problems: the orbit of the particles, and the physical structure of the swarm. The only observations involved in fixing the orbit are the position of the radiant and its change of position with zenith distance; in regard to the physical structure a variety of observations is possible. The following suggestions serve as an observing program for a single observer assisted by a recorder. If additional observers are available, the several types of observation may be delegated.

(*a*) *Orbital.* Determine as closely as possible the position and size of the radiant area, and, if possible, fix the position of the radiant when it is at several appreciably different zenith distances.

(*b*) *Structural.* 1. Have each observer record the magnitude, or identification, of the faintest star that he can see. If the transparency changes appreciably during the observations, record the stellar limit frequently.

2. Choose some specific region of the sky, *e.g.*, the polar region, or the

zenith, and count the number of meteors seen during intervals of five minutes.

3. At least once each hour count, over intervals of not less than five minutes, the number of meteors of each magnitude. A continuous record of the magnitudes of all meteors seen, from which any time-variations in the magnitude distribution may be found, would be extremely valuable.

4. If low-power binoculars or a comet-seeker are available, determine the number of meteors of various magnitudes seen through such optical instruments.

5. With a large party an attempt can be made to detect "groupings" among the particles; make "ten-second counts" according to the method discussed by Miss Hoffleit (*H. C.* 420, 1937).

6. Utilize whatever photographic equipment is available for securing both trails and spectra of the meteors. For detailed suggestions, see papers by P. M. Millman (*P. A.*, **41**, 298, 1933; *J.R.A.S.Can.*, **31**, 295, 1937; and "Amateur Telescope Making, Advanced," Scientific American Press, N. Y.)

7. When reporting the observations, give all the data which were obtained and descriptions of the field of view, time system, telescopes, etc., employed. At a later date superfluous information can be disregarded, but omitted data cannot be re-created. Observations of the shower strength and radiant position, when the zenith distance of the radiant is large, are of special value.

All observers should carefully plan their programs so as to obtain the maximum of results in the eventuality of a detectable shower. Continued investigation over many years of the Giacobinid system, in which both meteor showers and the comet may be observed, should greatly increase our knowledge about the structure of comets in general and the processes by which they disintegrate into meteor streams.

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, MASSACHUSETTS.

Planetary Motions and Lambert's Theorem

By PAUL HERGET

One of the problems which confronted the early astronomers was to explain the motions of the planets across the sky. The hundreds of visible stars all retain the same relative positions on the sphere of the sky and revolve in unison, but the planets, or "wanderers," move about among the stars in an almost unpredictable fashion.

Pythagoras supposed that each planet had its own transparent sphere upon which it could move independently, and that all the stars were fixed upon the outermost crystalline sphere. The sizes of these spheres were supposed to be such as would vibrate with musical harmony, thus giving rise to the idea of "the music of the spheres."

Ptolemy, in the 2nd century A.D., conceived of each planet as moving about a small imaginary circle, or epicycle, whose center moved about a larger imaginary circle, or deferent, which in turn had its center at the earth. The main deficiency of this scheme lay in the fact that it failed to recognize that the earth was not the center of the Universe. But still, it is possible to refer motion to any point as origin, and Ptolemy's system of deferents and epicycles would have been satisfactory if all the planetary orbits were really circles about the sun. The slight eccentricities required the addition of more epicycles, until the system became very complicated, but still not satisfactory when more observations were accumulated.

It is strange and unfortunate that the attack on this problem did not result in the discovery of Fourier series. It is now known that the elliptic orbit of a planet about the sun can be represented by a vectorial Fourier series where the only difference from Ptolemy's system is that the first epicycle rotates twice as rapidly as the deferent, the second epicycle three times as fast, etc. The size of each epicycle depends upon the Bessel functions of the eccentricity. Thus, if it had not been for the failure to realize the value of greater generalization or for the mental predilection which restricted the speed of rotation of the epicycles, this important mathematical theory could have been discovered many hundreds of years sooner.

Copernicus pointed out the greater simplicity of using the Sun as the center of motion, and Kepler finally discovered the laws of planetary motion. Newton's law of universal gravitation gave a simple mathematical basis upon which all future calculations were based. This made it possible to predict just where the planet would be and where the earth would be at any given time, and thus find the direction in which we, on the earth, would have to look to see the planet.

Using Newton's law of gravitation, the mathematical astronomer, Lambert, proved an important theorem concerning the nature of the apparent path, as seen from the earth, of any celestial object revolving about the sun. This theorem, though not difficult to demonstrate, is not often discussed in elementary books, yet it contains some exceedingly interesting and remarkable facts.

The following mathematical equation, when properly interpreted, tells the whole story.

$$K\,l'^2\,\Delta = k^2\,R \sin F\,(r^{-3} - R^{-3})$$

(Taken from Bauschinger, "Bahnbestimmung," p. 243.)

The meaning of the various symbols is illustrated in Figure 1. The sphere represents the whole sky, as seen from the Earth, E. As the Earth and a planet, P, move about the Sun, S, the apparent path of the planet, as seen projected onto the sphere of the sky, is shown by the curve, C. The tangent to C is always a great circle, T, (corresponding to a straight line in the plane). The Sun's path around the sky is shown

by the great circle, Ec, the ecliptic. The arc, F, is the the angular distance of the Sun above or below this tangent great circle.

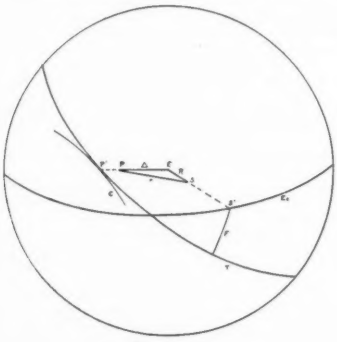

FIGURE 1

If the path of the planet is curved, the tangent great circle will be continually changing, and this is indicated by the curvature, K. The more rapid the change, the greater is the value of K. Whenever the object remains in the same great circle, either momentarily or indefinitely, there is no curvature and K is zero. V is the velocity of the object along its apparent path. Δ is the distance from the Earth to the planet, R is the distance from the Earth to the Sun, and r is the distance from the Sun to the planet. k^2 is merely a constant whose value depends upon the units used for the other quantities. All of the quantities in the equation except K and F must be positive.

If the path of the planet is curving toward the Sun, K and F will both have the same sign and *vice versa*. In the Figure, the path, C, is curving away from the Sun, so that in this case K and F will have opposite signs. Now, if r is smaller than R, then $(r^{-3} - R^{-3})$ is a positive quantity; therefore K and F must have the same sign or else one side of the equation would be positive and the other side negative, which is impossible. This means that in this case the planet will be curving toward the Sun. Similarly, if r is larger than R, then $(r^{-3} - R^{-3})$ is negative; K and F must have opposite signs in order that the equation may be true, and the planet will be curving away from the Sun. In practice, however, this information will be used in the reverse order: one observes that the path is concave or convex toward the Sun and concludes that the distance of the planet from the Sun is less or greater, respectively, than the Earth's distance.

For many comets which move in close to the Sun, r may first be larger than R, and then become smaller, or *vice versa*. There will then be a certain time when they are equal, which will cause the right side of the equation to vanish. On the left side, K will have to undergo corresponding changes, going from negative to positive or *vice versa*. At

the moment when r is equal to R, K will be zero and the motion will be along a great circle.

One must be careful, however, not to state this conclusion in the reverse order. If K is zero, that does not necessarily mean that r and R are equal. For objects like the major planets, which move almost exactly in the ecliptic, the curvature will naturally be very small, since the ecliptic itself is a great circle. This situation is also covered by the equation, for the path's tangent great circle will always be very near the Sun, and then F will always be very small.

Incidentally, such a situation adds to the difficulty of computing the orbit. The simple fact that the Sun, Earth, and planet form a triangle is expressed by the equation

$$r^2 = R^2 + \Delta^2 - 2\,R\,\Delta\cos\theta,$$

where θ is the angular distance in the sky between the Sun and planet, *i.e.*, angle $S'EP'$. This and the first equation are usually sufficient to solve for the planet's orbit, since r and Δ are the only unknowns. But if both sides of the first equation are zero, it is useless for this purpose, and some other means of solving the problem must be found.

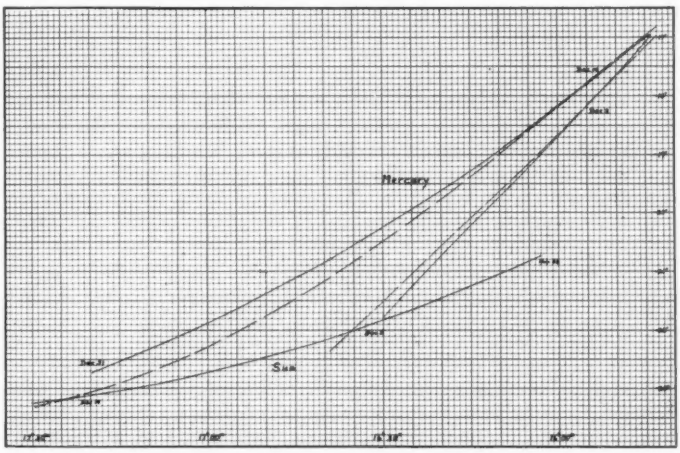

FIGURE 2

Finally, it is possible that the tangent to the apparent path may still be directed toward the Sun, making F zero, even though the planet does not move in the ecliptic or r equal R. In this case, K would again be zero and there would be no curvature. This is not a very ordinary case, and for that reason it is seldom mentioned. But it happens that this is exhibited twice by the planet Mercury during the month of December, 1939. In order to illustrate this and some of the other aspects of Lam-

bert's theorem, a graph of the motion of Mercury and the Sun during this month is shown (Figure 2).

The graph represents only a small portion of the whole sphere of the sky, and is necessarily somewhat distorted because a sphere cannot be exactly represented on a plane. The path of the Sun is part of the ecliptic great circle, *Ec*. The path of Mercury corresponds to the curve, *C*. The great circle tangents for December 3.55 and 14.78 U.T. are represented by broken lines. At these dates the tangents happen to pass through the Sun, so that F is zero, and therefore K is also zero. It can be seen by inspection that at any other time the tangent does not pass through the Sun, so that F would not be zero. For Mercury, r cannot equal R, so there would have to be some curvature to the path. Also, since r is less than R, the Sun will always be on the inner or concave side of the curve, *C*. This is very obviously the case around December 9. The relative values of V, the velocity along the curve, can be seen from the distances between the dots, which indicate one day's motion.

Thus we have another example of how concisely the mathematician can express facts to those who read his language; and we see how much information is contained in the equation which is the basis of Lambert's theorem.

CINCINNATI OBSERVATORY, FEBRUARY, 1939.

Planet Notes for July and August, 1939

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. Apparent positions of the sun are as follows:

	α h m	δ ° ′
July 1	6 36.0	+23 11.2
August 1	8 41.1	+18 18.5
September 1	10 37.4	+ 8 41.8

The sun is in the constellation Gemini until July 20, when it enters the constellation Cancer. It passes from Cancer into Leo on August 10. The earth will be at the aphelion point of its orbit, and at the maximum distance of 94,453,000 miles from the sun, on July 5. Values for the equation of time are as follows:

Date 1939	Equation of Time (Mean - Apparent) m s	Date 1939	Equation of Time (Mean - Apparent) m s
July 2	+ 3 38	Aug. 3	+ 6 9
6	+ 4 22	7	+ 5 48
10	+ 5 1	11	+ 5 17
14	+ 5 34	15	+ 4 38
18	+ 5 59	19	+ 3 50
22	+ 6 16	23	+ 2 53
26	+ 6 23	27	+ 1 49
30	+ 6 21	31	+ 0 39

Moon. Phenomena of the moon will occur as follows:

		h	m
Full Moon	July 1	16	16
Last Quarter	9	19	49
New Moon	16	21	3
First Quarter	23	11	34
Full Moon	31	6	37
Last Quarter	Aug. 8	9	18
New Moon	15	3	53
First Quarter	21	21	21
Full Moon	29	22	9
Apogee	July 5	14	
Perigee	17	23	
Apogee	Aug. 2	0	
Perigee	15	8	
Apogee	29	3	

Mercury. Mercury will be an evening star during July and the first part of August. The planet will be at greatest eastern elongation (26° 31′, magn. +0.7) from the sun on July 13, 19h. The planet will be inconspicuous in the evening sky, however, because of its low altitude at sunset. Inferior conjunction occurs on August 10, and thereafter the planet will be situated in the morning sky. Greatest western elongation occurs on August 28, 17h, at which time the planet will be 18° 16′ from the sun. The planet should at this time be discernible 10° above the east point of the horizon shortly before sunrise. The stellar magnitude at elongation will be +0.1.

Venus. Venus is a morning star during July and August, but close to the sun. On July 1 it rises an hour and a half before the sun and will be at an altitude of 12° by sunrise. By August 1 the planet will be too close to the sun to be easily identified in the morning sky. Venus may still be located in the daytime, however, as an object of stellar magnitude —3.5, situated 9° west and 3° north of the sun. By September 1 the planet will be too close to the sun for observation, except with large telescopes. Conjunction with the sun will occur September 5. Further data are given in POPULAR ASTRONOMY for January, 1939, p. 33.

Mars. Mars will be in opposition with the sun on July 23, 8h. The minimum distance from the earth will be 36,033,000 miles, which will be reached on July 27, 21h. This distance is only 4% greater than the minimum possible distance at opposition. At the time of minimum approach Mars will have an angular diameter of over 24″, so that an excellent opportunity will be afforded to view the planet, provided the seeing is good. The meridian altitude will be low, for northern observers, as the declination of the planet at opposition is —26°. The south pole of the planet will be visible during this opposition. Mars is in the constellation Capricornus during this opposition. Its motion is retrograde during July, and until August 24. Additional information is tabulated below:

Date 1939	Distance from Earth (Miles)	Angular Diameter	Stellar Magnitude
July 1	40,776,000	20″.3	—2.1
15	37,138,000	23.4	—2.4
27.9	36,033,000	24.1	—2.6
Aug. 1	36,144,000	24.1	—2.5
15	38,085,000	22.8	—2.2

Jupiter. Jupiter is an object of stellar magnitude —2.0, situated a few degrees east of the vernal equinox in the constellation Pisces. The planet rises above

the horizon about midnight on July 1. By September 1 it will rise some 4 hours earlier, and will have increased in brightness by 0.3 of a magnitude.

Saturn. Saturn is a morning star, and is also to be found in the constellation Pisces, 7° north of the star α Piscium. The stellar magnitude of the planet varies from +0.6 during July, to +0.4 by the end of August.

Uranus. Uranus is a morning object in Aries. This planet will be in quadrature with the sun August 15. An occultation of Uranus by the moon is predicted for July 12 (Time of conjunction, $11^h\ 57^m$ G.C.T.). Positions of Uranus are as follows:

	α	δ
	h m	° ′
July 1	3 13.1	+17 36.1
August 1	3 17.3	+17 52.2
September 1	3 18.5	+17 56.7

Neptune. Neptune is still observable in the evening sky, in the constellation Leo. Attention is again called to the chart which appeared in POPULAR ASTRONOMY for January, 1939, p. 33, illustrating the apparent path of Neptune among the stars.

Occultation Predictions

(Taken from the *American Ephemeris*)

OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.

Date 1939	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
July 8	25 Psc	6.1	7 12.2	..	..	357	7 45.8	..	..	309
14	*m* Tau	5.0	7 43.3	−0.2	−0.2	139	8 11.8	+0.7	+2.8	206
22	α Vir	1.2	23 17.9	..	..	178	23 51.0	..	..	228
26	ν Sco	4.3	1 58.6	−1.9	−0.7	97	3 21.7	−1.6	−1.2	273
27	109 B.Oph	6.2	1 38.6	−2.0	−1.8	145	2 31.2	−1.9	+1.2	219
28	16 G.Sgr	6.5	3 5.6	..	..	138	3 55.7	..	..	209
29	BD—19°5182	6.4	1 12.8	−1.8	+1.1	82	2 41.3	−2.1	+0.4	265
Aug. 10	302 B.Tau	6.1	8 36.4	−0.6	+2.1	60	9 43.0	−1.4	+0.7	279
12	26 Gem	5.1	7 10.8	0.0	0.0	135	7 47.6	+0.5	+2.2	226
19	BD—8°3495	6.4	0 9.3	−0.8	−1.6	110	1 11.9	−0.4	−1.6	284
20	α Lib	2.9	18 45.8	−0.7	−0.1	134	19 54.3	−1.7	+0.9	268
25	ρ Sgr	4.0	21 53.8	−1.0	+1.9	70	23 8.3	−1.3	+0.9	280
27	16 B.Cap	6.2	5 12.5	−0.8	+0.6	37	6 18.0	−1.4	−1.8	279
27	β Cap	3.2	5 19.6	−0.8	+0.4	42	6 27.4	−1.2	−1.6	274

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′.

July 26	ν Sco	4.3	1 21.7	−2.0	−0.2	108	2 49.9	−2.2	−0.4	272
27	109 B.Oph	6.2	1 20.3	..	..	175	1 38.5	..	..	199
28	16 G.Sgr	6.5	2 28.5	..	..	143	3 20.3	..	..	214
29	BD—19°5182	6.4	0 44.2	−1.0	+1.2	97	2 2.4	−1.6	+1.2	259
29	BD—18°5155	6.3	7 39.2	−0.8	−0.1	56	8 48.0	−0.9	−1.5	273
Aug. 9	148 B.Tau	6.0	10 16.9	−2.0	−0.1	115	11 17.7	−1.1	+3.0	215
10	302 B.Tau	6.1	8 26.6	+0.1	+2.3	46	9 18.5	−0.9	+0.5	292
10	*i* Tau	5.1	10 50.6	−1.2	+1.7	72	12 7.0	−1.8	+0.7	269
20	α Lib	2.9	18 45.1	+0.6	−2.6	172	19 15.8	−2.0	+3.7	228
27	16 B.Cap	6.2	4 53.1	..	..	15	5 45.9	..	..	302
27	β Cap	3.2	4 59.1	−0.9	+2.0	21	5 59.1	−2.7	−2.2	295

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′.

July	5	c^1 Cap	5.3	11	26.7	−2.2	+0.4	71	12	54.4	−1.4	+0.6	231
	9	60 Psc	6.2	11	3.8	−1.0	+2.6	37	12	20.3	−2.2	+0.7	266
	28	39 G.Sgr	6.3	9	0.6	−1.3	−1.1	91	10	11.2	−0.4	−0.5	245
	29	BD—18°5155	6.3	6	59.0	−1.6	+2.0	30	8	3.3	−2.9	−2.2	302
Aug.	9	148 B.Tau	6.0	9	40.7	−0.4	+1.2	90	10	42.6	−0.5	+1.9	239
	10	*i* Tau	5.1	10	27.3	0.0	+2.1	51	11	22.4	−0.9	+0.6	287
	25	89 G.Sgr	6.5	4	41.0	−3.0	−1.8	128	5	40.5	−1.4	+2.0	208

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

The Occultation of Spica

Because of the infrequency of first-magnitude star occultations, the conjunction of Alpha Virginis and the moon on May 1, 1939, was awaited here with considerable interest. Clear skies for several days previously gave hopes of excellent seeing conditions, but thin clouds and haze which persisted much of the same day caused some apprehension. When the moon appeared above a grove of trees about 7:00 P.M., its appearance was hazy and poorly defined. However, in the telescope the terminator showed good definition, and as soon as the sun set, about 7:18 P.M., Spica showed up well about 10′ distant, much to our satisfaction.

Since only thirty-six hours remained before full moon phase, the moon appeared almost circular, and we were prepared to see the star almost to the terminator line before immersion behind the narrow strip of the dark limb.

The occultation was a beautiful and an interesting spectacle, in spite of the light sky and the thin cloud sheet. Spica looked like a white diamond which hung poised for a few moments directly over the black concavity of the mountain-walled plain Riccioli on the terminator, and then suddenly vanished.

The time of immersion was $7^h\,38^m\,36^s.6$, P.S.T. Position of my observatory, Latitude 45° 29′ 44″, Longitude 122° 42′ 03″, elevation 1007 feet.

ROBERT E. MILLARD.

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Occultation of Spica on May 1, 1939

The immersion and emersion of Spica were observed by me under good atmospheric conditions but I am sorry to say that my observations are of no real value because I did not have a timepiece accurate enough for the purpose. However, I did make an attempt to determine the duration; this turned out to be $1^h\,9^m.7$ as compared with the value of $1^h\,8^m.6$ found from my tables as published in the April issue.

JACOB HERMANN.

Route 3, Box 105, Kenosha, Wisconsin.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

It is only occasionally that it has been possible for any considerable number of the A.M.S. to meet together, and it has been a rarer occasion still when I have had the pleasure of being present. However, such a chance did come about, thanks to an invitation from the Milwaukee Astronomical Society to give a talk before them on April 6 last. After the illustrated lecture, which happened to be on the related subject of comets, was over, about half of the audience gathered for an informal discussion of meteor work and how it could be carried out. As there were a number of regular A.M.S. members present, the discussion was most enthusiastic, and knowing the good work already done by the Wisconsin-N. Illinois group, I have every hope that the campaign planned on meteor heights for the summer and fall of 1939 will be their most successful contribution to meteoric astronomy. They are hoping to be able to use radio to keep in constant communication during the course of the actual observations, which should be of great use, especially in preventing uncertainties in timing, etc., which lead to misidentifications. I wish also to mention that I was driven by E. A. Halbach out to their new observatory, where I found instruments and equipment which it seems hard to believe that a group of amateurs, all busy in their regular professions, could possibly have designed, built and set up. The ease with which the dome, housing the 13-inch reflector, turns was remarkable. When I learned of the fine program they carry out, it was obvious that the Milwaukee Astronomical Society's members do more scientific work with their telescopes than is done in some professional observatories that I know of. Indeed they deserve the greatest praise for all they have accomplished already, under very considerable difficulties of many kinds, and I have rarely had a more inspiring day than that spent with them. When I add that their observatory is 15 miles west of the city, it will be seen that it takes real enthusiasm for men, busy in the daytime, to drive any such distance and spend half the night observing in the bitter cold. Its location is, however, a very fine one and the transparency they report is remarkable and helps pay for the troubles inherent in going so far. I only wish it were possible for me to visit other groups more often and have similar meetings with them.

The number of individuals who have so far sent in regular observations in 1939 is, as is usual in first part of the year, very small. This is due both to cold weather, low hourly meteor rates, and a dearth of prominent meteor showers. Of course other members have undoubtedly done some observing but have not yet sent in their records. I shall now give the data at hand in the following table. In so far as this partial information goes, it would seem that the January Quadrantids gave a poor and the April Lyrids a fair return only. I have a report from New Jersey on a splendid fireball, with an 8-minute train, that appeared at 9:45 on April 22. But the plot sent me indicates this object was not a Lyrid. I am most anxious to get other observations on this object; if any reader knows of a person who saw this fireball, please let me know, as it is specially important to get all possible data on long-enduring trains such as this was. May I also request that our members be more careful to put down for *every night* the condition of the sky, and also in-

dicate not only when they started and stopped observing but whether they observed during this whole interval. Lack of clearness in both items makes needless uncertainty and trouble in discussing the observations.

Observer and Station	1939	Began	Ended	Total	F	Met.	*
Khan, Mohd. A. R., Begumpet, India	Jan. 1	14:45	15:30	45	0.5	15	(1)
	2	15:00	15:30	30	0.5	0	
	3	15:20	16:30	70	0.4	20	(2)
McArthur, C., N. Quincy, Massachusetts,	Feb. 16	12:20	13:06	46	0.7	4	(3)
Stone, Wm. R., 1938	Dec. 31	10:30	13:00	150	0.6	3	(3)
Santa Barbara, California 1939	Jan. 2	10:30	14:30	240	0.4	10	(3)
	Apr. 20	11:00	13:30	150	0.9	6	(3)
	21	11:00	14:00	180	0.5	7	(3)
	22	11:00	13:30	150	0.6	7	(3)
	23	11:30	14:00	150	1.0	7	(3)
Avery, V., Banks, North Dakota	Feb. 17	8:39	10:41			4	(3)
	21	8:38	12:15			9	(3)
	Mar. 10	8:15	12:30	255		8	(3)
	15	9:15	10:50	95		1	(3)
	16	8:45	10:00	75		3	(3)
	17	8:30	10:00	90		1	(3)
	23	9:15	10:05	50		1	(3)
	24	9:00	13:50	290		6	(3)
	Apr. 11	9:08	10:35	87		2	(3)
	13	9:05	10:20	75		4	(3)
	17	9:05	14:02	297		3	(3)
	21	10:10	12:18	128	1.0	11	(3)
	Casuals					8	
Mastell, R., Hibbing, Minnesota	Mar. 12	11:00	11:30	30	1.0	3	(3)
	15	10:00	12:30	150	1.0	6	(3)
	16	11:52	13:45	113	1.0	6	(3)
	Apr. 21	11:52	13:50		0.5	21	(4)
Louisville Astr. Society, Louisville, Ky.							
Moore, W. L.	Apr. 22	12:00	14:30	90	1.0	17	(5)
Shepinski, Miss M.	22	12:00	14:30	90	1.0	16	(5)
Maris, N.	22	12:30	14:30	60	1.0	12	(5)
Kammer, M.	22	12:30	14:30	60	1.0	12	(5)
Savage, W. A.	22	12:30	14:30	60	1.0	8	(5)

*(1) Described. *(2) 5 Quadrantids. *(3) Plotted. *(4) Plotted; 11 Lyrids. *(5) Fine aurora 13:09 to 13:45. No observing 12:30 to 14:00. Counts; 4 plotted.

The last section of these Notes contains the results on two fireballs, which were worked out long since but laid away for revision. This has now been done. In both cases I have tried to point out quite frankly which of the derived data are and which are not entitled to confidence, as there is considerable variation as to this.

Fireball of 1931 April 30

On April 30, 1931, at 7:49 G.C.T., a brilliant fireball was seen over the Bahama Islands moving from north to south, its ending point being north of the west end of Santo Domingo. Observations of this object as seen from four ships were printed in the Hydrographic Bulletin of the U. S. Navy:

S1.—From U.S.S. *Brazos,* in latitude 19° 32′ N., longitude 73° 45′ W., the body was seen to "burst forth bearing 10° (true) at an altitude of 12°, [shoot] eastward parallel to the horizon, and disappear bearing 40°." It was visible from 20 to 30 seconds, and lighted the whole northeastern sky and horizon "like daylight." It "seemed to move with erratic speed, with vivid red, green, and yellow particles flying from it which

were plainly visible. It had the appearance of a bursting rocket during the entire flight."

S2.—From Amer. S.S. *Ancon*, in latitude 20° 36′ N., longitude 73° 47′ W., the meteor "appeared at an altitude of about 30° 20′, bearing 15° (true), [and] traveled slowly across the heavens in a southerly direction, increasing in brilliancy and lighting up the adjacent sky and sea, leaving a long trail of sparks. The meteor disappeared after about 8 seconds at an altitude of about 20° 10′, bearing 130°. The weather was fine and clear."

S3.—From Amer. S.S. *Pat Doheny*, in latitude 21° 41′ N., longitude 74° 19′ W., an exceptionally large meteor "appeared at an altitude of 40°, bearing 30°, and resembled a very large ball of fire sailing slowly across the sky in a 205° direction. A very bright bluish trail was left which illuminated the whole eastern sky and horizon. At an altitude of 10° the meteor burst into several fragments leaving only a quarter of its original size to pursue the same course. At an altitude of about 5° it seemed to stop for about 2 seconds after which it slowly faded out with a reddish hue. The body was visible for about 35 seconds. The weather was partly cloudy."

S4.—From the Amer. S.S. *Martinique*, in latitude 22° 02′ N., longitude 74° 20′ W., "a very brilliant green light appeared bearing east at an altitude of about 60°. The body traveled across the sky to the southward for about 3 seconds when it disappeared behind clouds at an altitude of about 20°, bearing south. This was the largest, brightest, and most lasting meteor the observer has ever seen, being many times brighter than any star or planet."

The first graphical method described on the back of Pilot Chart No. 1400 was used to work out these observtions. The observer at S4 evidently did not see either end of the path, the disappearing point being reported as behind clouds. Even at that, his longitude would have to be put considerably to the east of the point given if his observations were made to agree in the least with the others. The observations from S1 and S2 are complete in every detail, a sextant evidently being used on S2. For S3, beginning and end altitudes and beginning bearing are given, but instead of end bearing there is the statement that the ball sailed "slowly across the sky in a 205° direction." This can be interpreted logically only to mean that the object passed almost through the ship's zenith, and this evidently was not meant at all. The end point therefore depends upon observations from S1 and S2 only.

The beginning point was observed from S1, S2, and S3, but it was far to the north. The adopted point is the center of gravity of the triangle formed by the three converging azimuth lines, and at this point the outer lines make an angle of only 22°. This is unfortunate, as slight errors in azimuth would change the point's position very considerably.

From the data, used as judiciously as possible, the object began over $\lambda = 72° 56′$ W., $\phi = 23° 35′$ N., and ended over $\lambda = 73° 12′$ W., $\phi = 20° 09′$ N., its projected path being 380 km. long. Making the proper corrections to the observed altitudes for curvature of the earth, we find for the heights:

Station	Begin(km)	End(km)	Weight
S1	114.6	19.9	1
S2	224.5	29.0	2
S3	224.2	21.3	1
Adopted	196.8	24.8	

All the evidence justifies giving double weight to observations from S2. There is

no apparent reason why the beginning altitude from S1 is so low; to make it agree with the other two (which are in splendid accord) it would have to be increased by 14°. The end heights all agree well. While the observations from S4 are too poor to use, still the ship was in a position not far from perpendicular to the middle of the meteor's path. The altitude given by S4 at least tends to confirm the higher values for the beginning point.

The actual observed path in our atmosphere was 417 km. long, and the plane of motion lay in azimuth 184° and 4°. The local sidereal time at the end point was $17^h\,25^m$. The coördinates of the radiant altitude (corrected for curvature but not for zenith attraction) are therefore:

$$h = 22°.7;\ a = 184°.$$

As the estimates of duration differ so greatly, we make the assumption of parabolic velocity. The apparent radiant being about 102° from the meteoric apex and z being 67°.3, we find from the table that dz is −3°.8. When this correction is applied, the corrected radiant is found to be

$$h = 18°.9,\ a = 184°;\quad \text{or}\quad \delta = +86°,\ \alpha = 9°.$$

A search in the von Niessl-Hoffmeister catalogue shows no other fireballs from this radiant. We conclude that it did not belong to any well-known stream.

From the general description by all four observers, this object was a most remarkable fireball. As it disappeared so near the earth's surface, it probably furnished meteorites, which unfortunately fell into the sea. The cause of serious discrepancies in the reported duration seems to be confusion of the duration of the meteor itself with that of the meteor *and* its train. The color reported and other phenomena are typical of great fireballs of long paths, which penetrate deep into the atmosphere.

Fireball of 1931 June 23

The following two observations on a bright fireball were reported. The second was printed in the Hydrographic Bulletin:

1.—Officer G. P. Green of American S.S. *Steel Exporter* at 12:36 G.C.T., longitude 160° 36′ W., latitude 22° 16′ N., observed "a very bright meteor appearing at altitude 30° and bearing 220° true, disappearing at altitude 16°, bearing 250° true. Duration about 3 seconds. The meteor was red leaving a bright train of blue and red fire."

2.—Second Officer J. M. Muir, American S.S. *Hualalai*, ". . . 2:00 A.M. (ship time), in latitude 21° 39′ N., longitude 158° 47′ W., a bluish meteor was observed at an altitude of about 25°, bearing 260°. It disappeared at an altitude of about 15°, bearing 275°."

The solution for heights was made in the usual graphical way, plotting the azimuths (bearing ±180°) and then solving with the altitudes corrected for earth's curvature. The resulting values were:

Station	Beginning Height km	End Height km
1	99.8	41.4
2	156.6	95.8
Average	128.2±28.4	68.6±27.2

Examination of the data shows that assumption of a reasonably small error in the bearing from either ship would not help the solution appreciably. Apparently the errors lie in the positions of the ships or more probably in altitudes. Fortun-

ately the slope of the path is not much affected whether we use only the values for station 1 (S1), or those for S2, or the average. The meteor radiant was

$$a = 349°, h = 35°; \quad \text{or} \quad \alpha = 308°, \delta = -31°.$$

Its projected path was 85 km. long; its real path, 104 km. Using the G.C.T. for S1, we find the local sidereal time to be $19^h\ 56^m$.

The solution was made first by R. H. Wilson, then of the Flower Observatory staff.

Flower Observatory, Upper Darby, Pennsylvania, 1939 May 4.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
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The Goose Lake Siderite: California's Largest Known Meteorite

By FREDERICK C. LEONARD

ABSTRACT

A siderite discovered near Goose Lake in northern Modoc County, California, on 1938 October 13, by Messrs. Joseph Secco, Clarence A. Schmidt, and Ira Iverson of Oakland, has recently been identified and just been recovered, through the coöperation of five fellows of the Society for Research on Meteorites, namely, Dr. and Mrs. H. H. Nininger, Professor Earle G. Linsley, Dr. Robert W. Webb, and the writer. This meteorite is by far the largest found up to date in California, the official weight being 2573 pounds (1167 kilograms). The overall dimensions of the mass, which is a medium octahedrite, are 3 ft. 10 in. × 2 ft. 4½ in. × 1 ft. 8 in. Because all of the original fusion crust is lacking, it is inferred that the meteorite is a very old fall.

Through the coöperation of five fellows of the Society for Research on Meteorites, namely, Dr. and Mrs. H. H. Nininger of the Colorado Museum of Natural History and the American Meteorite Laboratory, Denver, Professor Earle G. Linsley of the Chabot Observatory and Mills College, Oakland, California, Dr. Robert W. Webb of the Department of Geology of the University of California, Los Angeles, and the writer, the largest meteorite discovered up to date in the State of California, and probably the fifth largest meteoritic mass known to have fallen within the United States, has recently been identified and just been recovered. The meteorite, which is an iron, or siderite, was found on 1938 October 13, by Messrs. Joseph Secco, Clarence A. Schmidt, and Ira Iverson of Oakland, while hunting deer at a place in northern Modoc County, about 2 miles west of the western shore of Goose Lake and 1¼ miles south of the California-Oregon state line (coördinates approximately, long. W. 120° 32′.5, lat. N. 41° 58′.6). The meteorite was removed from the place of fall on 1939 May 3 and 4, by a party, of which the

aforementioned fellows of the Society were members. Since the specimen was located in the Modoc National Forest, it is the property of the Smithsonian Institution and the United States National Museum; however, through the kindness of Dr. Alexander Wetmore, the Assistant Secretary of the Smithsonian Institution, the body will be on exhibition at the Golden Gate International Exposition in San Francisco until the conclusion of the fair. (Since the opening of the Exposition, a small but representative collection of meteorites has formed a part of the astronomical exhibit of the University of California.)

FIGURE 1
THE GOOSE LAKE, CALIFORNIA, METEORITE *in Situ*
As Seen from the Northeast

The overall dimensions of the meteorite, which is a very irregular mass, deeply pitted, perforated, and unoriented, and which resembles in shape, more than anything else, a gigantic molar tooth, are 3 ft. 10 in. × 2 ft. 4½ in. × 1 ft. 8 in. The official weight is 2573 pounds (1167 kilograms). Etching the polished surface of a small fragment with dilute nitric acid revealed the characteristic Widmanstätten figures, which indicate that the specimen is a medium octahedrite. The more weathered parts of the surface of the meteorite are a wind-polished maroon, while the parts which have lain near or in contact with the soil are cinnamon-brown or rust-colored. Because all of the original fusion crust is missing, it is concluded that the meteorite is a very old fall. The mass rested in the center of an almost circular, saucer-like depression or "crater," about five feet in diameter and one foot deep. This formation was the only visible evidence, if evidence it was, of the impact of the body with the ground. As no postoffice is situated within a radius of several miles of the spot where the meteorite was discovered, and it was near no well-known geographical feature other than Goose Lake, it shall be called the Goose Lake, Modoc County, California, meteorite.

This magnificent siderite constitutes the eleventh known California fall, if Muroc and Muroc Dry Lake (*v.* H. H. Nininger and C. H. Cleminshaw, *C.S.R.M.: P. A.*, **45**, 273-5; **1**, No. 3, 23-5, 1937), are regarded as distinct falls, and it is by far the largest known California meteorite, the next largest being the 425-pound Owens Valley, Inyo County, iron, discovered in 1913, the main mass of which is

preserved in the United States National Museum. Goose Lake, while probably the fifth largest individual meteorite known to have fallen within the United States, is certainly the third largest meteorite on record for the three Pacific Coast States, the only larger ones ever found in this area being the great 15½-ton Willamette, Oregon, iron, which is the largest meteorite recovered anywhere in the country, and the lost Port Orford, Oregon, pallasite, whose weight has been estimated to be 11 tons. It is noteworthy that, of the ten described California falls—Windmill

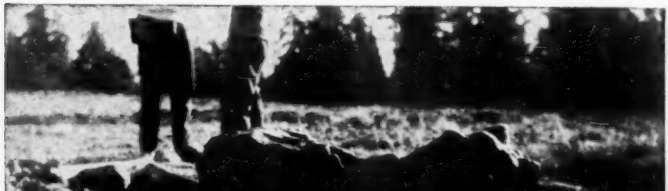

FIGURE 2
THE GOOSE LAKE, CALIFORNIA, METEORITE *in Situ*
As Seen from the Southeast

Station, found in 1929, has unfortunately never been described—all are irons except San Emigdio, Muroc, and Muroc Dry Lake, which are stones. This fact is doubtless partly explainable by the circumstance that siderites are in general, on account of the nature of the topography, much more easily detectable in California than are aërolites.

Widmanstätten Figures in Terrestrial Alloys

By ROBERT M. LEARD,
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ABSTRACT

The three components of the Widmanstätten figures in nickel-iron alloys are discussed. Kamacite is described as a solid solution of nickel in iron, taenite as probably a solid solution of iron in nickel, and plessite as a eutectoid of the two. Experiments leading to the production of a synthetic octahedrite and of a synthetic hexahedrite are reported, and the case for the presence of figures in the Greenland iron is summarized. Attention is called to the presence of Widmanstätten figures in alloys other than those of nickel-iron.

INTRODUCTION

The Widmanstätten figures, familiar to meteoriticists as a common structure in the nickel-iron alloy of meteorites since their discovery in the Agram [Hraschina], Croatia, Jugoslavia, meteorite by Alois von Widmanstätten in 1808, have been

accepted as a criterion for meteoritic origin. However, as their presence in manufactured and natural terrestrial nickel-iron and in other alloys is now known, it is the purpose of this paper to discuss the appearance of the figures in the various materials, and thus to give some idea as to the possible cause of such well-developed figures in nickel-iron alloys of cosmic origin.

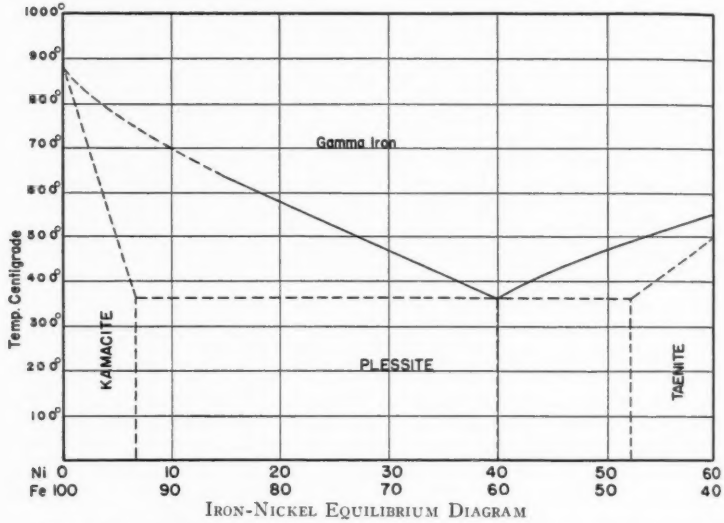
THE FIGURES IN METEORITES AND IN MANUFACTURED NICKEL-IRON

Upon megascopic examination of the figures on a polished and properly etched surface of an octahedral siderite, one sees sets of bands or ribbons intersecting one another and forming closed figures or areas. It is observed further that these bands are plane sections of plates which are found to be oriented parallel to the eight faces of an octahedron (111), the angle at which the bands intersect depending upon that at which the section is cut in relation to the octahedron (see Farrington's *Meteorites,* Figs. 37-40, p. 94, 1915). The central part of each band is found to be made up of an alloy of nickel-iron in a ratio of about 14 : 1.[1] This substance is iron-gray in color, relatively soluble in dilute HCl, and has been called *kamacite* (also *camacite* or *Balkeneisen*). Its composition is fairly constant, and a formula $Fe_{14}Ni$ has been assigned,[2] but this formula expresses in no way a chemical union, for such would be hardly reconcilable with known principles of chemistry. These bands are bounded by borders of a white alloy, scarcely attacked by dilute HCl, termed *taenite* (*Bandeisen, meteorin,* or *edmondsonite*). The nickel content is variable, the ratio of Fe : Ni + Co varying from 6.9 : 1 to 1.1 : 1. The interstices between the bands are filled with a fine aggregate of kamacite and taenite, which sometimes repeats the larger octahedral figures on a smaller scale, and sometimes appears to be a heterogeneous mass which seems to be uniform on cursory examination, but which, if magnified, is found to be always a mixture of kamacite and taenite. This filling has been termed *plessite* (*Fülleisen*), and may be thought of as a eutectoid of the two chief constituents, kamacite and taenite.[3]

It has been observed that the nickel content of the nickel-iron alloy of metallic meteorites determines their classification, and thus may be correlated with the formation of the three aforementioned substances. If the iron contains less than 6%-7% nickel, only kamacite will form, and a cubic iron meteorite, or hexahedrite, will result. Thus, kamacite may be thought of as a solid solution of nickel in iron, the nickel being soluble at normal temperatures up to the limit of 6%-7%. If the percentage of nickel is above this figure, the excess will go into the formation of taenite, or plessite (taenite + kamacite), but there is still much doubt as to the exact nature of taenite. According to the diagram proposed by Osmond and Cartaud (see the accompanying figure), this material may be a solid solution of iron in nickel, the iron being soluble at temperatures below 360° C., up to about 51%-52%.

An early production of synthetic Widmanstätten figures was made in 1908 by N. A. Ziegler,[4] when he left ingots of 0.5% carbon-steel in a furnace shut down for the Easter holidays. The slow cooling produced a "geometric pattern" that was later, for the first time in terrestrial alloys, recognized as a Widmanstätten structure. Later, experiments by Benedicks,[3] based upon the tentative equilibrium diagram, have given some very interesting results. This investigator prepared a nickel-iron alloy (12% Ni) by the reduction of a mixture of the oxides by aluminium powder (the Goldschmidt or thermite process), and allowed the resulting melt to cool very slowly from above 700° C. to 50° C. The cooling intervals ranged from 65[h] to 100[h]. The resulting metal, while it did not consist of a single crystal, as do most siderites, did contain some grains as large as 20 × 25 mm. These grains

showed a definite structure visible to the naked eye, and microscopic examination revealed clearly that the alloy had separated into two phases, probably kamacite and taenite. The structures or figures bore a very strong resemblance to figures in the N'Goureyma, Jenne, Massina, French West Africa, meteorite of 1900 June 15, which is a peltoid, breccia-like octahedrite. The synthetic octahedrite, as it might be called, just referred to, did not lose its structure upon annealing at 350° C. for 42^h, but the alloy was recrystallized when heated to 490° C. for 3^h. Hence, the critical range for separation of the two phases takes place somewhere between these two temperatures, and is taken as 360° C. in the diagram previously cited. Accepting the results of the foregoing experiment, we should conclude that Widmanstätten figures, approaching those of meteorites in size, could be produced by very slow cooling of a nickel-iron alloy containing 10%-20% Ni, particularly through the region about 360° C.



IRON-NICKEL EQUILIBRIUM DIAGRAM

(From Benedicks' *Metallographic Researches*, after Osmond and Cartaud)

The reason that the segregations assume the positions they do, *i.e.*, as planes parallel to the faces of an octahedron, is not well understood, but it would seem to be related to a weakness of the iron crystal along the (111) plane, as it is known that both native iron and manufactured iron have an octahedral cleavage which would point to some weakness in that direction.

Derge and Kommel[5] made X-ray studies of the patterns in the Canyon Diablo, Arizona, irons and in the Bethany [Amalia Farm], Great Namaqualand, South Africa, meteorite, and also produced synthetic figures, by cooling an alloy of 27% Ni-73% Fe from 1400° C. to room temperature in 12^h, which were visible to the naked eye. Benedicks likewise succeeded in producing a synthetic cubic "meteorite" by the same process, using an alloy containing 6.7% Ni, in which the fractured surface showed fine cubes and bore a very strong resemblance to the fracture of hexahedrites.

THE FIGURES IN NATURAL TERRESTRIAL IRON

Native iron, as a mineral, is extremely rare, and is seldom confused with meteoritic iron when found. However, the largest and best-known occurrence of terrestrial iron, that at Ovifak, Disko Island, Greenland, is a notable exception. This deposit was discovered by Nordenskiöld in 1870.[6] He described many masses, some as great as 21 tons in weight, weathering out of the basalt sea-cliff and lying along the beach. This material was thought by him to be due to a great fall of meteorites into the basalt flow while it was on the surface in a plastic state, probably some time in the Miocene. This conclusion was based upon the fact that the iron showed, "when polished and etched, the peculiar markings [Widmanstätten figures], usually considered characteristic of native iron of meteor[it]ic origin,"[7] and that it contained from 2.19% to 5.06% Ni.[8] Steenstrup[9] redescribed this occurrence, and found iron in veins, masses, and dendrites in the basalt, and concluded that the iron must have been extruded with the basalt. It may either have been reduced from the iron compounds in the basalt, or have been carried up from a great depth. The former explanation appears to be the more plausible one, as coal beds are known to underlie areas in that region, and, further, the basalt contains free carbon, as graphite, in rather large amounts.[10]

Farrington[11] states, in speaking of the Greenland iron, that "no typical octahedral figures or other meteoritic figures are exhibited on etching." Buddhue[12] also doubts the presence of Widmanstätten figures in this iron, on the ground that the average of 11 analyses gave: 92.15% Fe, 1.72% Ni, 0.55% Co; and, as he could find no analysis of meteoritic material giving less than 2% Ni, he suggested that the original investigators cited previously were mistaken in their identification. However, Clarke[13] gives several analyses over 2%, and states that ". . . it gave Widmanstätten figures when etched." Further, Kulik[14] has suggested that the Greenland iron represents meteoritic material brought from the central plateau by ice sheets and deposited in the terminal moraine. Although this explanation can hardly be credited in the light of the evidence cited previously, it does show that the question is still open, and could be settled best by a re-examination of the original material by an authority well versed in both meteoritics and petrogenesis. Numerous other occurrences of native iron, both primary and secondary, are given by Clarke,[15] but none has been confused with meteoritic material as has been the Disko Island iron.

Inasmuch as many metals have a face-centered cubic structure, and thus favor precipitation of another metal from solution along the octahedral planes of the parent phase, it is not uncommon to find Widmanstätten figures in alloys other than those of iron and nickel. Van Wert[16] gives some excellent illustrations of the Widmanstätten structure in the following alloys: gold-copper, copper-tin (59% Cu), gold-copper-zinc, copper-zinc (40% Zn), iron-manganese (30% Mn), and 0.53% carbon-steel. All these figures are small in comparison with those observed in the nickel-iron alloy of meteorites, and are seen only by microscopic examination, with magnifications ranging from 100 to 500 diameters.

In conclusion, the writer wishes to express his thanks to Dr. Frederick C. Leonard, Chairman of the Department of Astronomy of the University of California, Los Angeles, at whose suggestion this paper was written.

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The Words Aërolite, Ethaërial, and Widmanstätten

In the interest of simplicity in nomenclature, the Editor ventures the following suggestions relative to three—two of them very common—meteoritical terms:

(1) That *aërolite* (correctly pronounced ā′-ĕr-ō-līt, but almost universally mispronounced!) be changed to *airolite* (pronounced âr′-ō-līt) This change does not obscure the etymology of the word, but obviates the dieresis, and makes the term easier to pronounce.

(2) That the adjective *ethaërial* (pronounced ēth-ā-ē′-rĭ-ăl), recently proposed by Nininger (*v. C.S.R.M.: P. A.*, **47**, 97-9; **2**, No. 2, 79-81, 1939), be shortened to *ethrial* (pronounced ēth′-rĭ-ăl). The word is obviously a contraction of *ether* + *aërial*.

(3) That the spelling of *Widmanstätten* (pronounced Vĭd′-măn-stĕt-ĕn), even though it is a proper name or title (*v.* F. A. Paneth, *C.S.R.M.: P. A.*, **46**, 469-71; **2**, No. 1, 56-7, 1938), be altered, once and for all, to *Widmanstetten*. The substitution of the *e* for the *ä* in no way affects the pronunciation of the word, since, as has been pointed out, short *e* and *ä* are indistinguishable in speech, but simplifies the writing of the name, at least in English, by eliminating the umlaut.

F. C. L.

Members Elected as Fellows of the Society

At a special meeting of the Council of the Society, held in the Department of Astronomy of the University of California, Los Angeles, on April 14, 1939, the following members of the Society were elected as fellows. The members of the Council in attendance at this meeting were President H. H. Nininger, Secretary R. W. Webb, and Councilors G. M. Butler, (Ex-President) F. C. Leonard, and W. T. Whitney. Mrs. Addie D. Nininger, a fellow of the Society, was present by invitation.

Mr. E. R. Bartlam, Ceylon Technical College, Colombo, *Ceylon*
M. F. W. Cassirer, 5 Rue Raffaelli, Paris 16, *France*
Dr. Axel Corlin, Astronomical Observatory, Lund, *Sweden*

Mr. Fred G. Hawley, International Smelting Co., Box 351, Miami, Ariz.
Dr. Samuel Herrick, Jr., Dep. of Astronomy, University of California, Los Angeles, Calif.
Dr. (Miss) Dorrit Hoffleit, Harvard College Observatory, Cambridge, Mass.
Mr. Robert R. McMath, McMath-Hulbert Observatory, University of Michigan, Route 4, Pontiac, Mich.
Mr. R. C. Vance, Woodland Rd., Long Meadow, Pittsford, N. Y.

ROBERT W. WEBB, *Secretary*

New Meteoritic Finds from Wabar, Arabia, and Joe Wright Mountain, Arkansas

By HENRY W. NICHOLS,
Chief Curator of Geology, Field Museum of Natural History, Chicago, Illinois

A party of geologists from the California Arabian Standard Oil Company, Jidda, Arabia, recently reached the meteorite crater at Wabar, Rub'al Khali, Arabia, and obtained for the Field Museum, two small individuals, weight 62.3 grams, of the Wabar iron, and a specimen of the silica glass. This is, so far as is known, the only expedition to reach Wabar since Philby discovered the crater in 1932.

A second individual of the Joe Wright Mountain, Arkansas, iron was found last year about 10 miles north and 10° west of the original find. The new find weighs 20 pounds, 10 ounces, and is now in the Field Museum.

A Large Meteor in Texas

A very large meteor fell into the Gulf of Mexico on the evening of May 1 at about 8:20 P.M. The writer at his home in Austin happened to be looking eastward and caught sight of it as soon as it became visible. It seemed to have originated in the region of constellations Lyra and Hercules and moved approximately south, passing directly over the face of the nearly full moon. It had exploded before the writer caught sight of it, but the fragments were yet very close together. As seen at Austin it appeared very much like a large rocket, but became lost to vision very shortly after passing over the moon, which was then about thirty degrees above the horizon. Down at Houston it appeared very much larger, and was called a giant, being twice the size of the full moon, and there seemed to leave a train which wavered a short while. From both Houston and Galveston it was seen to disappear in the Gulf. No bursting noise nor any smell was noticeable at any place. From the fact that, seen at Austin, it was no larger than a rocket, while at Houston and Galveston it appeared twice the size of a full moon, we infer that it went into the Gulf some twenty or thirty miles out.

GEO. B. HUFFORD.

1609 Evergreen Avenue, Austin, Texas, May 4, 1939.

Large Meteorite Exhibited

Mills College, Oakland, California, classes in astronomy and the Eastbay Astronomical Association had an out of the ordinary experience when Professor Earle G. Linsley brought to the very doors the giant meteorite of 2,573 pounds recently recovered from the Modoc lava beds in the National Forest in northeastern California.

All had an opportunity to see the meteorite in the "raw" for the truck was

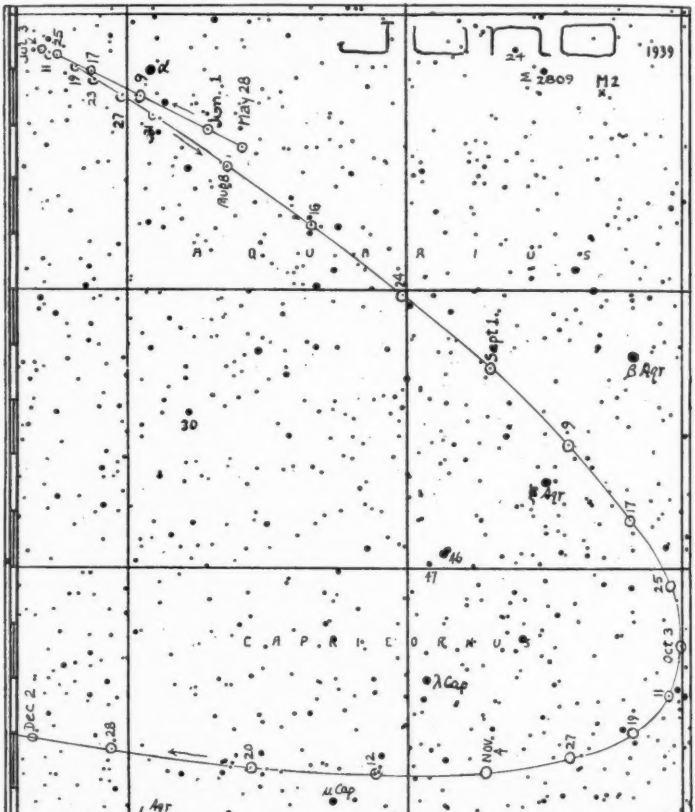
parked practically at the class-room door. The meteorite was exhibited for a week at Chabot Observatory and is now at Treasure Island, University of California astronomical exhibit, for the duration of the Exposition.

It will be the property of the Smithsonian Institution, Washington, D. C.

Asteroid Notes

By HUGH S. RICE

The minor planet 3 Juno is the best object of its kind for small-telescope observation during the early summer. The accompanying chart depicts Juno's apparent path in the sky from May until the end of the year. On June 1 the magnitude is 9.5; on July 1, 9.0; while on August 1, 8.5. As opposition does not occur until August 19, the asteroid will afford good material for following, for several



months. The diagram shows several small stars with which Juno comes into conjunction in its path across the stellar fields.

On the chart the positions are for 7:00 P.M., E.S.T. They were taken from the ephemerides published by the Astronomisches Rechen-Institut at Berlin-Dahlem, Germany. Computation was by Dr. F. Gondolatsch. The right ascension and declination were given for 1939 and we reduced these positions to corresponding coördinates for 1855. This reduction was for the purpose of fitting them to Beyer-Graff's *Stern-Atlas,* whose equinox is 1855, and which is reproduced herewith.

The asteroids 1 Ceres and 2 Pallas are not in a position for observation until late in the year. The other one of the "big 4"—No. 4 Vesta—is also observable this summer, but during June and July rises very late and is not as suitable as Juno during this period. On June 25 Vesta is in Pisces, 5° nearly west of α Piscium, and the magnitude is 7.9. On July 31, it is in Cetus, 6° approximately northeast of the same star. We expect to publish a chart of its apparent path in the next issue of this magazine.

There are four other asteroids that may be picked up by astronomers at this time, and we give the ephemerides below, as computed by the Rechen-Institut. The equinox is 1950, in conformity with standard computing practice.

ASTEROID EPHEMERIDES. FOR 0^h U.T. EQUINOX 1950.

43 ARIADNE ($8^M.8$)

		α h m	δ ° ′
May	25	17 47.6	—24 46
June	2	17 41.9	—24 20
	10	17 34.8	—23 51
	18	17 27.0	—23 18
	26	17 19.6	—22 45
July	4	17 13.5	—22 12

18 MELPOMENE ($9^M.1$)

		α h m	δ ° ′
June	10	18 58.8	— 8 17
	18	18 52.9	— 8 19
	26	18 45.6	— 8 33
July	4	18 37.5	— 8 58
	12	18 29.3	— 9 35
	20	18 21.5	—10 21

10 HYGIEA ($9^M.1$)

		α h m	δ ° ′
June	10	18 47.0	—24 16
	18	18 40.9	—24 14
	26	18 34.2	—24 11
July	4	18 27.3	—24 6
	12	18 20.7	—23 59
	20	18 14.8	—23 51

7 IRIS ($8^M.7$)

		α h m	δ ° ′
June	18	19 24.8	—18 52
	26	19 17.7	—18 45
July	4	19 9.6	—18 41
	12	19 0.9	—18 37
	20	18 52.4	—18 35
	28	18 44.6	—18 33

Hayden Planetarium, American Museum of Natural History,
New York City, May 18, 1939

Comet Notes

By G. VAN BIESBROECK

COMET 1939 *d*. The central bureau of astronomical telegrams at the Harvard College Observatory reported April 18 the discovery of an unexpected comet as bright as third magnitude. The first information about this object was received through S. Rosseland, director of the observatory at Oslo, Norway, who reported that an observer, Hassel, had sighted the newcomer in the evening of April 16 in the approximate position: Right Ascension $1^h\,27^m$, Declination +41°. The comet was at that time in Andromeda almost exactly in conjunction with the sun which made it most conspicuous in northern stations. As usual such a bright object was

noticed independently by several observers; two Russian amateurs, Achmarof at Balesino and Jurlof in Votkinsk, reported to the Pulkova Observatory that they had found it on April 15. Further independent early discoveries were made by L. V. Smith at Segewick (Alberta, Canada) on April 16, E. W. Barlow (England), and E. Buchar (Prague) on April 18, C. L. Friend at Escondido (California) and Kozik at Aschabad (Russia) on April 19 and many more later. It would be impractical to attach so many names to the designation of 1939 *d* but the central bureau of the Astronomical Union at Copenhagen has decided in such cases to limit the names to three. This comet will therefore be called Jurlof-Achmarof-Hassel (1939 *d*). When first discovered it made a beautiful sight especially in a binocular. It showed a large round coma with diffuse edges and a bright central

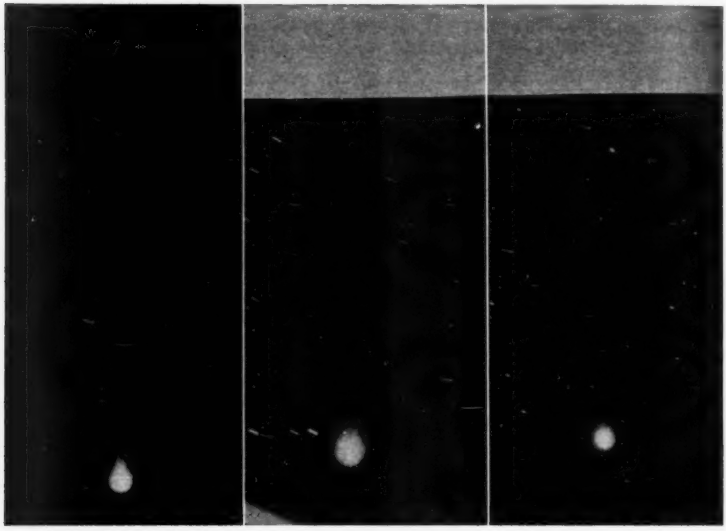


FIGURE 1 FIGURE 2 FIGURE 3

COMET 1939 *d* (JURLOF-ACHMAROF-HASSEL)

April 20 April 23 April 25

nucleus; besides there was a conspicuous tail, traced to a length of at least 20° by Quenisset at Juvisy (France). Figures 1, 2, and 3 are short exposures obtained by the writer with the 24-inch reflector of the Yerkes Observatory. The dates are April 20, 23, and 25. They show the rapid changes in the inner part of the tail composed of a bundle of numerous smaller streamers. A great many observations have been made on this object. Moving eastward through Perseus and Auriga it was well situated in the evening sky in the latter part of April but soon lost in brightness. Many orbits became available; they showed that the comet had been nearest to the sun on April 10. The following elements computed by A. D. Maxwell from an interval of two weeks (April 19, 25, and May 3) are evidently quite accurate; no marked deviation from a parabolic orbit is apparent, so that the period must be very long.

ELEMENTS OF COMET 1939 *d*

Date of perihelion	1939 April 10.17922 U.T.	
Perihelion to node	89° 15′ 50″.7	} 1939.0
Longitude of node	311 24 46.7	
Inclination	138 6 15.0	
Perihelion distance	0.528287	

EPHEMERIS (1939.0)

1939	α h m s	δ ° ′	—Distance from— sun	earth	M
May 13	6 9 3	+28 2	0.902	1.378	6.7
21	28 11	24 6	1.035	1.638	7.7
29	41 30	21 6	1.169	1.881	8.5
June 6	6 51 52	19 52	1.301	2.104	9.3
14	7 0 33	+16 44	1.432	2.308	9.9

The comet was nearest to the earth about the time of perihelion so that it must have been quite bright in the morning sky before discovery but probably too close to the sun to be easily seen. The magnitudes given in the above ephemeris are based on an estimation of $6^{M}.6$ on May 12 by the writer. The rapid decrease in brightness will soon put an end to the visibility as the angular distance to the sun decreases in June. By July 13 there will be conjunction with the sun.

COMET 1939 *e*. The fifth comet of the year is the expected reappearance of Periodic Comet Kopff. It was found by the writer on a pair of plates taken shortly before sunrise on April 22; it appeared as a centrally condensed coma 30″ in diameter; the total magnitude was estimated as 13.5 but this estimate is uncertain on account of the low altitude at which the observation was made. The discovery position is

1939 April 22.40248 $22^{h}\,19^{m}\,38^{s}.44$ −5° 12′ 21″.0

When compared with the ephemeris published by F. Kepinski the residual is only $+0^{s}.2$ and −3″ showing that this is the most precise prediction of a periodic comet ever made. This comet has now been observed at four returns since its first discovery by A. Kopff in Heidelberg in 1906. The period is 6.6 years. It passed perihelion on March 13 of this year and will change little in brightness in the coming months.

EPHEMERIS OF PERIODIC COMET 1939 *e* (KOPFF)

1939	α h m	δ ° ′	1939	α h m	δ ° ′
June 2	23 39.9	+ 6 7	July 4	0 24.8	+13 26
10	23 52.9	8 7	12	32.7	14 55
18	0 4.7	10 1	20	39.1	16 15
26	15.4	11 48			

The two comets 1939 *b* and *c* mentioned last month are still favorably situated for observation: the first one is slowly fading as expected and can only be seen with powerful telescopes. From the observations on March 20, 25, and April 8, T. J. Bartlett, H. A. Panofsky, and Miss E. L. Scott, students in Berkeley, have deduced improved elements as follows:

Perihelion	1939 April 25.77256	
Perihelion to node	44° 4′ 20″.9	} 1939.0
Longitude of node	135 24 41.3	
Inclination	11 19 24.3	
Eccentricity	0.637066	
Period	10.7453 years	

This is one more well-established member of the family of periodic comets.

COMET 1939 *c* (PERIODIC PONS-WINNECKE) is rapidly gaining in brightness, having reached magnitude 12.5 on May 10. This is more than a magnitude brighter than is given in the ephemeris on p. 281, which is being continued here:

EPHEMERIS OF COMET 1939 *c* (PONS-WINNECKE)

1939	α h m	δ ° ′	M
June 2	15 6.0	+42 29	12.0
6	9.2	40 4	
10	13.6	36 41	11.7
14	19.4	32 2	
18	27.0	25 33	11.4
22	37.0	16 31	
26	15 50.1	+ 4 14	11.1
30	16 6.8	−11 8	
July 4	16 28.1	−27 37	11.0

Maximum brightness is reached at the end of June at which time it should be easy to locate the comet traveling southward through the constellation of Serpens.

Williams Bay, Wisconsin, May 16, 1939

Comet 1939*d*.—On the original plate of a fifteen-minute exposure of Comet 1939 *d* which was taken at Smith College Observatory on April 21 the tail can be traced for a distance of four to five degrees. On a short exposure made soon after this, a fairly well-defined nucleus elongated in right ascension—not in the direction of the tail, apparently—could be seen. Whether this was an illusion or not, I do not know. The position angle of the tail is about 23°.

DOROTHY N. DAVIS.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Z Camelopardalis-Type Variables, 1937-38: Continuing the presentation of observational features concerning special types of variable stars, begun in the previous issue with a discussion of the SS Cygni-type variables, we now give for the same years similar facts for most of the known Z Camelopardalis-type stars.

Besides the type-star, Z Camelopardalis and the well-observed similar variable RX Andromedae, there are at least three others that appear to belong to this class: TZ Persei; — Draconis, 195377; and CN Orionis. Variables of this type are closely allied to the SS Cygni-type stars, except that the former are usually of smaller range, have shorter mean cycles, and are subject to long intervals during which little variation in light is apparent. Facts concerning these five stars are enumerated below:

Name	Designation	Magnitude Max.	Min.	Cycle days	Spectrum
RX And	005840	10.5	13.3	8-40	
TZ Per	020356	12.5	[15.0	15-25	f:
CN Ori	054705	11.9	[14.6	15-20	
Z Cam	081473	10.2	13.5	11-35	F
— Dra	195377	11.9	14.6	10-15	

The light curves are shown in Figure 1 on the usual scale (100 days equal four magnitudes).

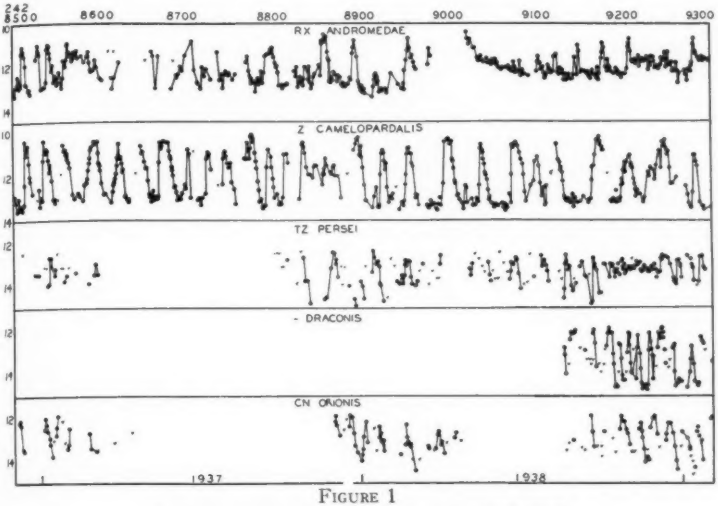


FIGURE 1
Z CAMELOPARDALIS-TYPE VARIABLES, 1937-1938

Intervals of anomalous behavior for RX Andromedae were noted early in 1937 and at longer intervals during 1938. Similar behavior on the part of TZ Persei occurred toward the end of 1938.

All of these stars including BI Orionis—not as yet regularly observed on the A.A.V.S.O. program—require close attention if their vagaries are to be carefully noted. Most of them are best observed in telescopes of large aperture and by observers of considerable experience.

Z Andromedae: The behavior of the nova-like variable Z Andromedae, 232848, during the last half-century has been studied recently by Dr. Richard Prager in the course of the work of the Harvard-Milton Variable Star Bureau. The most interesting portion of the photographic light-curve is reproduced in Figure 2, cov-

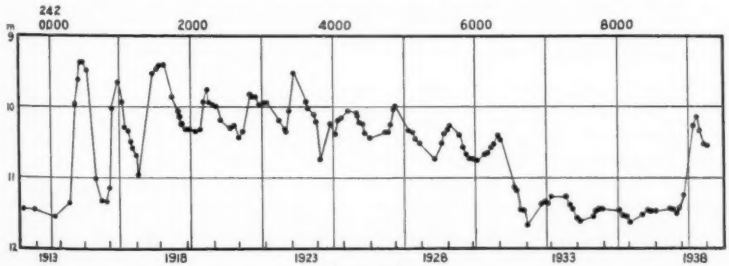


FIGURE 2
PHOTOGRAPHIC LIGHT CURVE OF Z ANDROMEDAE, 1912-1939

ering the interval 1912 to 1939. After several years of nearly constant brightness, approximately of magnitude 11.0, the strongest outburst observed since 1901 took place in 1914, when the star reached magnitude 9.4. This outburst was followed by successive waves with an approximate period of 650 days, a slowly decreasing amplitude, and with a brightness gradually becoming fainter. During 1931 the mean brightness dropped suddenly and remained near the eleventh magnitude until 1938, when a new outburst occurred, attaining magnitude 10.1, but not reaching the height of those that occurred in 1901 and 1914.

Visual observations made since 1922 confirm in almost every detail the form of the curve derived from the photographs, although there is a systematic difference in magnitude between the two light curves amounting to $0^{M}.75$, which may be due, in part at least, to difference in color.

When the star was discovered by Mrs. Fleming in 1901, she recorded the spectrum as "bright lines, nova or variable?" The spectrum did at that time resemble the spectrum of Nova Persei 1901, as well as that of Nova (RS) Ophiuchi 1898.

That the star Z Andromedae is composed of two components can be scarcely doubted, from the evidence of these periodic outbursts. The variations are probably caused by the activity of the bluer star, the red component having little, if any, effect on the change in brightness. The star certainly has nova characteristics and it may, in times past, have had a genuine bright maximum. In recent years it may have been undergoing the variations usually found in a nova in its late stages.

If we assume a cycle of 650 days, the next increase in magnitude should occur in May, 1940.

Variable Stars and the Galactic Center: Again the study of Cepheid variables comes to the aid of the astronomer in determining the distance to the center of our galactic system. In a paper read before the National Academy of Sciences in March, Dr. Shapley outlined his most recent attack on this problem which was based on a study of more than 200 Cepheid variables in Milky Way Field 269, centered at $18^{h}\,20^{m}$, —55° (1900), galactic coördinates 307°, —20°, from plates taken at Bloemfontein.

Maximum frequency of Cepheids in MWF 269 is attained at magnitude 15.3. With the aid of the Bruce telescope plates, the survey may be considered complete to magnitude 16.0; and from a study of galaxies down to magnitude 17.4 in the same region, Dr. Shapley obtained a satisfactory idea of the degree of space transparency to be expected there.

He concludes that if the assumption that the maximum frequency distribution of cluster-type variables in the field implies a more or less symmetrical distribution of variables toward the galactic center, then the distance to the center is 9.7 kiloparsecs (with a mean error of 1.2 kp), or of the order of 30,000 light years.

Wachmann's Nova-Like Star: The announcement of a suspected nova in Orion—1.1939 Orionis—by A. A. Wachmann in January of this year has aroused considerable interest among variable star observers. When first discovered, the star was of the ninth photographic magnitude.

Dr. Dorrit Hoffleit has recently examined Harvard plates covering the region of this star and finds that between 1921 and December 1936 it was approximately of the sixteenth magnitude, displaying oscillations amounting to a magnitude. She also found the first positive evidence of the slow, progressive rise from minimum of what appears to be a slowly-developing nova. On December 15, 1936, the star was of the magnitude 13.7, probably then on the rise toward maximum. We have

a previous instance of similar activity in Nova (RT) Serpentis 1909, which apparently took 40 days to rise from minimum to near maximum; but our information rested solely on one positive and three or four negative observations. In the present instance we have positive observational evidence throughout the entire rise, involving an increase in photographic magnitude from 13.7 to 12.3 in 33 days, and from 12.2 to 10.7 in 13 days, an interval of time almost identical to that required by RT Serpentis. Subsequently the rise became more gradual, and between October, 1937, and February, 1939, this nova-like star remained at practically constant maximum magnitude, 9.7. The following table gives selected values illustrating the behavior of the star from December, 1936, to March, 1939, on a provisional photographic scale.

Date	J.D.	m_{pg}	Date	J.D.	m_{pg}
1936 Dec. 15	2428815	13.7	1937 Dec. 7	2428875	9.7
1937 Jan. 16	8550	12.3	1938 Feb. 20	8950	9.8
Feb. 10	8575	10.5	Nov. 22	9225	9.7
Mar. 27	8620	10.0	1939 Jan. 16	9280	10.0
Sept. 23	8800	9.7	Mar. 17	9340	10.2

It appears now to be attached to a nebula, according to information by Dr. Dieckvoss of Bergedorf; and Graff points to several similarities between it and R Monocerotis, which is also associated with a variable nebula—further confirmation of the star's identification as a nova.

There has been a tendency in the past few weeks toward a slight decrease in brightness, but in view of the fact that RT Serpentis—the prototype of the Wachmann nova-like star—increased by about a magnitude (with minor fluctuations) during the ten years following its original outburst, continued observations, both visual and photographic, should prove fruitful.

Observers and Observations during April, 1939

Observer	Var.	Est.	Observer	Var.	Est.
Albrecht	51	79	Holt	91	201
Baldwin	67	126	Houghton	89	245
Ball, A. R.	14	15	Howarth	15	20
Ball, J.	22	27	Irland	11	16
Bappu	29	80	Jones	51	107
Blunck	9	13	Kanda	3	14
Bouton	33	35	Kearons	42	63
Brocchi	10	17	Kelly	15	25
Buckstaff	7	16	deKock	60	101
Callum	13	13	Loreta	160	374
Carpenter	20	25	Lundquist	3	9
Dafter	8	24	Mages	55	128
Diedrich	8	8	Maupomé	28	28
Economou	5	5	McLeod	14	23
Ensor	35	37	Meek	51	473
Escalante	70	148	Millard	23	27
Fernald	33	35	Palo	5	10
Ford	24	24	Parker	27	27
Franklin	20	22	Peltier	9	38
Gomi	5	45	Prinslow	12	18
Gregory	52	52	Rademacher	2	2
Halbach	43	49	Recinsky	11	21
Harris	16	16	Riegelman	21	24
Hartmann	128	227	Rosebrugh	15	35
Heckenkamp	7	10	deRoy	13	39
Hiett	18	38	Russell	6	6
Hildom	25	35	Ryder	9	9

Observer	Var.	Est.	Observer	Var.	Est.
Schoenke	13	15	Treadwell	8	8
Seely	7	10	Webb	22	23
Seibel	14	15	Weber	31	31
Sill	28	29	Williams	6	15
Smith, F. P.	16	18	Yamada	4	22
Smith, J. R.	18	18	Yamasaki	38	38
Topham	11	12			
			Total Observations		3326

May 11, 1939

Notes from Amateurs

Cleveland Astronomical Society

Our annual dinner meeting, on Friday, April 28, brought out most of the membership as usual. This event is always well attended and marks the end of the winter series of lectures and regular meetings. Our president, Dr. Nassau, secured a distinguished scientist of Harvard College Observatory to lecture to us. Dr. Bart J. Bok is a speaker with a long and successful career in public exposition. He gave us an explanation of the most recent conceptions of our galaxy. "Gauging the Heavens" as developed by Dr. Bok gave us much new material to think about. Among the most startling theories is the increased number of stars in the globular clusters that seems to be indicated by the work of some astronomers but possibly not fully accepted as yet by the majority. The slides shown, taken at Harvard College Observatory with the fine photographic telescopes there available, were the best in definition ever shown here. The contrast of the negatives was unusual. Of added interest was the fact that Dr. McCusky of Case School of Applied Science is a co-worker in this field. Attention was directed to the work of the largest telescopes in exploring to the greatest depth in the galaxy but most of the counting and investigation is still due to the small photographic telescopes. The number, distribution, and position relative to each other of the millions of spiral nebulae making up the galaxy is probably the most fascinating of all astronomical fields of research. We shall remember Dr. Bok.

The dinner was served in the Russet Cafeteria and a pleasant room was provided for the showing of slides and the lecture.

The brightest comet since 1910 is now visible with binoculars in the evening sky and we have been watching its progress and trying to secure a few photographs.

DON H. JOHNSTON.

Euclid Beach Park, Cleveland, Ohio, May 1, 1939.

The New Haven Amateur Astronomical Society

The meeting of the New Haven Amateur Astronomical Society held on May 2 showed a record attendance of forty-seven. The Reverend Mr. and Mrs. Kearons of Fall River were the guest speakers and both delivered very interesting and instructive addresses.

Mrs. Kearons spoke on "Observing Variable Stars" and gave a brief account of her own experiences and routine followed in her observing. Practically all of her work is done in her attic with a portable 3-inch refractor which at first caused her considerable trouble owing to the mounting being quite unsteady, but with corrections made she has done some very creditable work by using two windows

on either side of her house. She stated that variable star observing began about 300 years ago, at which time observers first began to notice and wonder at certain gradual changes in the magnitude of certain stars. In addition to extensive variable star work Mrs. Kearons has also done some valuable work during the past fifteen years on sun-spot observing and has sent in monthly reports of her observations to Switzerland.

The Reverend Mr. Kearons in his address spoke in detail of his work in observing sunspots augmenting the work of his wife. He stated that there has been a steadily growing interest in sunspots as their effects are so noticeable on the radio-telephone and telegraph as well as their unquestionable influence upon our weather. The spots are tremendous cyclones of disturbance on the sun and occur in eleven-year cycles, the maximum years being 1917, 1928, 1939. Despite the fact that 1939 should have been a maximum year, 1937 showed much more activity than does 1939. From the 7th to the 13th of October, 1938, there occurred the largest group of sunspots observed in 100 years, measuring 135,000 miles long by 40,000 miles wide. He stated that Mr. Clayton has gone deeply into the influence of sunspots upon the weather, covering wide areas. It is known that at the period of maximum spots there is more rain while at minimum period a corresponding low rain fall. The level of water in certain lakes has been observed and in Victoria Nyanza in South Africa the rise and fall of the water level correspond with the curve of sun-spot activity. He also stated that Dr. Andrew E. Douglass has studied and proven that tree ring growth study bears out the cycle of sunspots for hundreds of years.

Professor Haubert Gillette has studied the thickness of clay deposits in Colorado and Nevada and there again for 300,000 years these deposits coincide with sun-spot cycles. The clay deposits in New England for 3,000 years show the same conditions. Beginning in 1650 for some unknown reason these eleven-year cycles ceased for 75 years.

Mr. Kearons by means of slides showed many graphic charts showing sun-spot activity in both the northern and southern hemispheres of the sun, and these showed that as a rule when the northern part was most active the southern hemisphere was quieter and *vice versa*. He stated that the difference in temperature of the solar surface and that of the spots was about 3000 degrees Centigrade.

After their very interesting talk to a very appreciative audience the group motored to the home of Dr. and Mrs. Rademacher where a reception was held.

May 10, 1939. F. R. BURNHAM, *Secretary*.

Amateur Astronomical Society of Los Angeles

The April meeting of the Amateur Astronomical Society of Los Angeles was held, as usual, on the second Thursday of the month, April 13, at 2606 West 8th Street. The speaker of the evening, Dr. Ernest C. Bower of the Griffith Observatory and Planetarium, was introduced after the routine business had been disposed of. Dr. Bower had chosen for his subject, "The Mass and Orbit of Pluto," a matter upon which he is a recognized authority, due to his work while a member of the Berkeley Astronomical Department of the University of California, and the Lick Observatory.

His opening remarks were devoted to a brief historical sketch of the discovery of Uranus in 1781 by Herschel, and the brilliant mathematical work of Adams and Leverrier which led to the detection of Neptune in 1846. The first work on the theory of a trans-Neptunian planet was by W. H. Pickering, who published a

series of papers on the subject. This was followed by Percival Lowell's analysis, in 1914, of the perturbations of Uranus, which led to results similar to those of Pickering. A search was made photographically in 1916 at the Lowell Observatory, but nothing was found. In 1919 a series of plates was taken at the Mount Wilson Observatory, but the search on these for the planet was also unsuccessful. Over a decade later, these plates were re-examined, and the image of the planet found upon them. Owing to extreme faintness, and distance from the center of the plates, it was missed on the earlier search. In 1929, a 13-inch photographic refractor, designed specially for the search, was installed at Lowell Observatory, and on March 13, 1930, it was announced that a fifteenth-magnitude object had been found with a motion corresponding to that of the predicted "Planet X."

Dr. Bower, by means of lantern slides, showed the preliminary orbits computed for Pluto, and the one finally adopted, which gave an inclination of seventeen degrees and a period of 248 years. Due to its great orbital eccentricity, Pluto at perihelion actually comes closer to the sun than Neptune, but because of the high inclination, there is little danger of a collision, as Pluto would pass high above Neptune.

There has been a great deal of argument as to whether the predictions of Lowell and Pickering, which actually fell within two degrees of the actual position of the planet, were only "happy accidents." Lowell worked with the perturbations of Uranus, which, however, were very small, due to its distance from the disturbing planet. Pickering employed the perturbations of Neptune, in which case, although the perturbations were larger, the planet had not been followed more than half-way around its orbit, so that its motion was not known with sufficient accuracy. A tabulation of the actual residuals that would have been produced by a planet with the mass of Pluto, which is probably less than three-tenths that of the earth, shows that the data upon which the predictions were based were due, not to the perturbations of Pluto, but principally to errors of observation. Therefore, the true orbit of Pluto could not be derived from them, considering its almost imperceptible mass.

Dr. Bower's fine lecture was greatly appreciated by the audience, which was composed of about fifty members and friends. It was announced that at the next meeting of the Society, the speaker would be Dr. Edison Pettit of the Mount Wilson Observatory, who would exhibit his motion pictures of solar prominences. In the past few months, we have been very fortunate in having a series of fine speakers, including Dr. Ferdinand Ellerman, Dr. Seth B. Nicholson, and Mr. William H. Christie of Mount Wilson, Dr. Mars F. Baumgardt and Mr. A. M. Newton of this Society, and Dr. Bower at this time.

After the meeting, refreshments were served, and a heliostat constructed by Mr. J. Foster Nelson, President of the Society, was on exhibition. It is equipped with a 6-inch flat, driven by clockwork, and an image-forming mirror of 27-foot focus. The Society's coelostat, designed for direct solar photography, is finished, as far as the optical parts are concerned. It has two Pyrex flats, of 6- and 8-inch diameters, and a 5-inch achromatic objective of 42-foot focus. It will probably be in operation in a short time.

GEORGE HERBIG, *Secretary.*

April 16, 1939.

Convention of Amateur Astronomers

A call to all amateur astronomers of the country is being issued from New York City through the Amateur Astronomers Association of the American

Museum of Natural History. Echoes of response are hoped for from the far corners of the United States and possibly Canada.

With a stellar attraction already in progress in New York, it was deemed a good time to have enthusiastic watchers of the skies gather this summer to discuss mutual problems; to promote a greater amateur interest in the stars and a more closely allied fellowship among the different societies in the country. Never has such a large undertaking been started before, but there is probably no better society to assume the leadership than the Amateur Astronomers Association of New York.

As a preliminary warm-up, it is planned to have an exhibition of amateur astronomical equipment in the American Museum of Natural History, arranged from material submitted by different societies who would like to exhibit—such as telescopes, photographs, drawings, etc. An exhibition committee will pick the outstanding entrants for the display, which, it is estimated, over 20,000 people will probably view.

Then the two day convention when all the society representatives who have come to New York will gather into groups according to geographical proximity to form plans for getting together and discussing mutual interests and problems. There will also be outstanding guest speakers of the astronomical world—both amateur and professional—a special "show" at the Hayden Planetarium, a banquet, and good time for all. But to insure success there must be active coöperation and interest from those groups who would like to participate.

Complete details may be obtained from the April and May issues of "The Sky," publication of the Hayden Planetarium, the A.A.A. of the American Museum, or the writer, Lewis Doolittle, South Norwalk, Connecticut. The dates: Exhibit July 30-August 20, ending with the convention.

And a special call to the amateur telescope makers: It is planned to hold the convention in August to allow amateurs to participate, attend the World's Fair, and also the telescope makers convention in Springfield, Vermont, all within the span of a "two-weeks' vacation."

The Visibility of the Milky Way

Is there a time in the year when no part of the Milky Way is seen in the dome of the sky? The answer is that in the early summer, in the early part of the night, in the lower part of the United States, no part of the Milky Way is seen lying across the sky.

The explanation is this. The pole of the galactic circle (the Milky Way) is located at about 180° in Right Ascension and 30° in Declination, placing it in the constellation Coma Berenices. Now as the parallels of latitude on the earth correspond with the parallels of Declination in the sky, it is evident that any stars lying on a given parallel of declination will pass directly overhead for all places located on a similar parallel of latitude. Now the constellation Coma Berenices, having a declination of about 30°, will, accordingly, pass directly overhead for all places located on the 30th parallel of latitude. This means that the pole of the Milky Way will be at the zenith, and the Milky Way itself—the medial line of it—will at all points, be 90° from the pole, consequently on the horizon all the way around. The Milky Way being a path of some ten to twenty degrees width, the upper or northern half of it will be seen. At this time the said top half of all the Milky Way may be seen at the same time, including that portion that dips farther south, lying in the constellations Norma, Centaurus, Crux, and Argo Navis; and,

in western Texas, where the air is free from moisture and haze, Alpha Centauri and Alpha Crucis are visible also.

At this time the northernmost constellation of the galactic circle, Cassiopeia, will be on the northern horizon directly under the North Pole.

In latitudes farther north where the North Pole will be higher, the northern part of the circle will also be higher and will not lie on the horizon as at the latitude stated. The regions where the phenomenon is visible are those of latitude and season as stated, *viz.*, northern Florida, Alabama, Mississippi, New Orleans, and middle and lower Texas, near Austin and San Antonio. The hours will be from about 8:00 to 10:00 P.M. in May and June, and just about sunset in July.

Austin, Texas. GEO. B. HUFFORD.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Additional Notes on Sphaera Mundi

Permit me to add a few words of comment to the historical article by Mr. E. Taylor, published in the April number of this journal (pp. 194-196) on the book *Sphaera Mundi* by Joseph Blancanus.

(1). Joseph Blancanus was born at Bologna in 1566 and died at Parma in 1624 June 7. He was a member of the Society of Jesus, a pupil of Father C. Clavius in Rome, and the preceptor of Father J. B. Riccioli, both of the same Society. He was professor of mathematics at Parma for many years, until his death. His Italian name was Giuseppe Biancani (Latin: Blancanus).

The book in question: *Sphaera mundi, seu cosmographia, demonstrativa, ac facili Methodo tradita: in quo totius Mundi fabrica, una cum novis Tychonis, Kepleri, Galilaei aliorumque astronomorum adinventis continetur. Accessere: I.—Brevis introductis ad Geographiam; II.—Apparatus ad Mathematicarum studium; III.—Echometria, idest Geometrica traditis de Echo,* was published, the first time, in Bologna in the year 1620, and again in Modena in 1630, 1635, 1653. The last two editions (of 1635 and 1653) have a IV appendix on: *Novum instrumentum ad Horologia describenda, opus posthumum.*

Father Biancani was a defender of the Ptolemaic System and an opponent of the Copernican System, which he characterized as "absurdissimus" not only for many scientific arguments but also for this reason "Ecclesiastica authoritate, tamquam sacris literis adversa, inhibita est." *Sphaera Mundi,* edit. of 1620, p. 75.

In spite of his opposition to the heliocentric doctrine, Biancani paid deference and respect to his friend Galileo; in a lette to the Jesuit Father, C. Griemberger, of date 1611 June 14, he said *"is amo ed ammiro Galilei, non solo per la sua rara dottrina ed invenzione, ma anco per l'antica amicizia che gia contrassi con lui in Padova."* (I love and admire Galilei, not only for his rare learning and invention, but also for the old friendship that I had with him in Padua.) However, in the dispute for priority of the discovery of sunspots he was against Galilei and on the side of the Jesuit Father, Chr. Scheiner.

Biancani published also another book on: *Aristotelis loca mathematica ex universis ipsius operibus collecta & explicata . . . Accessere de natura mathematicarum scientiarum tractatis: atque clarorum mathematicorum chronologia.* Bononia (1615).

J. Biancani was one of the first astronomers that observed Saturn, as a globe with two companions (the rings), as early as the end of October, 1616. Galilei saw it, in about the same appearance, in July, 1610, and Scheiner in February, 1614.

His observations are quoted by Huygens in *Systema Saturnium: "Etenim aliae deinceps mirabiles ac prodigissae formae apparuerunt, quas primum a Josepho Blancano & Francisco Fontana descriptas novimus."* Chr. Huygens.—*Oeuvres complètes.* Haye, Vol. XV (1925), p. 227, and p. 281 note 4. Riccioli.—*Almagestum novum,* I, p. 488, col. I, Biancani's observations on Saturn are in his *Sphaera mundi,* p. 292 of the edition of Bologna 1620, and at p. 155 of the edition of Modena 1635 and 1653, at the paragraph: *De duobus Saturni Comitibus;* there are also four rough sketches of Saturn's appearance.

Biobibliographical notes on Joseph Biancani are in: Riccioli.—*Almagestum novum,* I, p. XXXIX; Weidler.—*Historia Astronomiae,* p. 440; Riccardi.—*Biblioteca matematica italiana,* I, col. 127; Sommervogel.—*Bibliothèque de la Compagnie de Jésus,* I, col. 1436-7.

(2). The name that Galilei gave to the four greatest Jovian satellites was "medicea sydera" and not "medica sydera" or drug stars, as is said in Mr. Taylor's article. This name Galilei gave in honor of the great duke (granduca) of Tuscany, Cosimo II of the Medici's House (from family name Medici, the adjective medicea), to which Galilei dedicated his famous book: *Sydereus Nuncius.*

Pio Emanuelli.

Vatican Observatory, Rome, Italy, May 3, 1939.

The Causes of Tides

It is commonly supposed that the gravitational attraction of the moon and sun on the earth is the cause and the only cause of tides. While it is here admitted that gravitational attraction of the moon and sun on the earth does produce tides, the question is raised as to whether or not all of the force which causes tides is due to gravitation alone.

Tidal accelerations are caused by the fact that points on the earth's surface nearest the attracting body are attracted towards that body more than the average for the whole earth and the points farthest from the attracting body are attracted less than the average. The result is a tension in the earth in a direction parallel to the line joining the centers of the earth and the attracting body.

A similar tension must exist in the moon due to the attraction of the earth and the sun.

In order to simplify the problem the moon, as it is affected by the earth, will be considered. The moon always presents the same face to the earth and thus its revolution around the earth is very similar to a ball on the end of a string which is swung around in a circle. Gravity corresponds roughly to the string which keeps the moon from flying away on a tangent. Centrifugal force keeps the moon from falling to the earth. The total centrifugal force is equal to the total gravitational pull so that the earth and moon keep at the same distance apart, approximately. If the moon were stopped in its revolutionary motion around the earth there would be no centrifugal force and the moon would immediately start to fall

to earth. The part of the moon nearest the earth would be attracted more than the average for the moon as a whole and would tend to pull away from the balance while the part of the moon farthest away from the earth would be attracted less than the average and would be dragged by the balance of the moon, producing the tidal tension in the moon. Thus there would be tidal accelerations even though the moon did not revolve around the earth. This would be a strictly gravitational tidal acceleration.

The moon does revolve around the earth, however, and on account of this motion there are centrifugal forces which are brought into play. This total centrifugal force is equal to the total gravitational force which it tends to and does counteract, but, like the gravitational force it does not affect all points on the surface of the moon with equal strength. Centrifugal force varies directly as the square of the velocity and inversely as the radius. From this it is very apparent that points on the surface farthest away from the earth are acted upon by a centrifugal force greater than the average for the moon as a whole and points on the surface nearest the earth are acted on by a centrifugal force less than the average for the moon as a whole. Although acting outward instead of inward (toward the earth) as gravity does, this centrifugal force should produce tidal accelerations just as gravity does.

Another way of expressing the condition described in the preceding paragraph is to say that the total centrifugal force exerted by the moon as it revolves around the earth is the sum of the centrifugal forces of all the particles of which the moon is composed but the amount which each particle contributes is not the same as that contributed by other particles, some contributing more and others less due to the velocity around the earth and the distance from the earth.

The moon rotates on its axis once each month, the direction being from west to east—the same as the direction in which the moon revolves around the earth.

Suppose the moon were to rotate more rapidly than it now does. Under this condition the part which each particle of the moon would contribute to the total centrifugal force would be changed from what it now is. Those particles on the side of the moon away from the earth would be traveling at an increased velocity around the earth and would contribute more than before to the total while those particles on the side of the moon towards the earth would be traveling at a slower velocity around the earth and would contribute less than before to the total centrifugal force. The total centrifugal force would not be changed much, if any, however. (An exact mathematical discussion might and probably would show that an increase in speed of rotation of the moon would actually increase the total centrifugal force of the moon as it revolves around the earth and cause the moon to move outward and away from the earth, the gravitational attraction of the earth on the moon remaining the same except as the moon's distance from the earth increases causing a decrease in attraction on that account.)

An interesting feature of this theory is that the rotation of a satellite or planet in a direction which is reverse to that of its revolution would cause a compression or low tide effect on the sides nearest to and farthest away from the center of revolution. The reason for this is that the particles nearest the primary would have a higher velocity than the average and would also have a shorter radius, both of these facts tending to increase the centrifugal force while the particles on the side farthest from the body about which the satellite or planet is revolving would have slower velocity and longer radius than the average, which would tend to give it less centrifugal force than the average.

A few rough calculations have been made in order to determine in a general way the relative strength of the gravitational and centrifugal tidal accelerations, with the following results:

Using miles and seconds as the units it is found that the strictly gravitational tidal acceleration on the moon caused by the attraction of the earth is .000,000,087,8 while the tidal acceleration on the moon caused by the fact that the centrifugal force on the side of the moon away from the earth is greater than, and the centrifugal force on the side nearest the earth is less than the average is .000,000,007,5. Thus the centrifugal effect is about one-twelfth of the gravitational effect.

Using the same units and considering the tidal effect of the sun on the earth it is found that the tidal effect due to gravity alone is .000,000,05 while the tidal acceleration due to centrifugal force is .000,000,12. Thus it would seem, if the theory is correct, that centrifugal forces due to revolution and rotation are about 2.4 times as effective in creating tides as gravity alone is, in this case.

April 29, 1939.

General Notes

Mr. Philip E. Bliss, president of The Warner & Swasey Company so well known for the construction of much astronomical equipment in use today, died on Tuesday, April 11, 1939.

Dr. B. Lyot gave The George Darwin Lecture on May 12 in the rooms of the Royal Society, Burlington House, London. The subject of his lecture was "Solar Prominences Cinematographed at the Pic du Midi."

M. Bernard Lyot, of the Meudon Observatory, has been elected a member of the Section of Astronomy of the Paris Academy of Sciences in succession to the late A. de La Baume Pluvinel. (*Nature,* April 8, 1939.)

Sir James Jeans recently received the honor of having the Order of Merit conferred upon him. He is the third astronomer to receive this distinguished award, the two previous recipients being Sir William Huggins and Sir Arthur Eddington.

Dr. H. H. Nininger, Director of the American Meteorite Laboratory, Curator of Meteorites in the Colorado Museum of Natural History, Denver, and President of the Society for Research on Meteorites, lectured at the University of California, Los Angeles, on April 12, 1939, on the subject of "Our Stone-Pelted Planet." The lecture was illustrated with meteoritic specimens, lantern slides, and motion pictures, and was given under the auspices of the Department of Astronomy.

The Louisiana State University has just installed a Clark refractor with an aperture of 11½ inches. This is believed to be the third refractor in size in the South. Both the telescope and the 20-foot revolving dome were made by Alvan Clark and Sons Company. The new observatory was dedicated on April 25, the principal address of the occasion being delivered by Dr. W. L. Kennon, Professor of Physics and Astronomy at the University of Mississippi, who spoke on "Astronomy in America."

The Rittenhouse Astronomical Society of Philadelphia held its regular monthly meeting on Friday, May 12, 1939, in the Hall of The Franklin Institute. A lecture on the subject "Some Light upon Light" (with demonstrations) was given by Dr. Richard M. Sutton, Associate Professor of Physics, Haverford College.

Sphaera Mundi.—As a foot-note to the Quotations from the Sphaera Mundi on pages 194-196 it may be of interest to say something of the author. He was Giuseppe Biancani, a native of Bologna (in Latin Bononia), who was born in 1566, two years after Galileo and five years before Kepler. The Sphaera Mundi was his most important work and was republished after his death (1624). He was professor of mathematics in Parma. One of his pupils was Riccioli, the author of the system of lunar nomenclature now in use, who put his teacher on the moon in the Latin form of Blancanus, applied to a large crater near Clavius in the Southern hemisphere of the moon. Riccioli also published another of Blanchinus' books, the Instrumentum Horologicum.—T. L. MacDonald.

A Brilliant Aurora

From midnight to 3:30 (E.D.S.T.) on the morning of May 2 I witnessed the most brilliant and most active auroral display which I ever saw. A brilliant drapery formation was short-lived. Rapidly moving pulsating arcs moved almost instantaneously from the horizon to the zenith for some time. Even when the intensity of the moving forms had decreased considerably, the activity was still great. After the sun came up I looked for spots on the sun. There was a large, intense group present, but it was about 33° east of the meridian, so it is rather difficult to see the connection. Perhaps the activity was so intense that corpuscles emitted at glancing angles were sufficiently strong to excite the aurora.

Dorothy N. Davis.

Smith College Observatory, Northampton, Massachusetts.

The Franklin Institute Medal Awards for 1939

Among the fifteen awards of The Franklin Institute of the State of Pennsylvania, for scientific ingenuity and skill, for invention and discovery, presented in Franklin Hall of the Institute at its Medal Day exercises, Wednesday afternoon, May 17, the following are related directly or indirectly to researches in astronomy:

The Edward Longstreth Medal, founded in 1890 by Edward Longstreth of Philadelphia, retired member of the Baldwin Locomotive Works, for the encouragement of invention will be awarded this year to John Strong, Ph.D., Asssitant Professor of Physics in Astro-physics, California Institute of Technology, Pasadena, California, and to Robley Cook Williams, Ph.D., Department of Astronomy, University of Michigan, Ann Arbor, Michigan, "In consideration of their independent development and improvement of a process for coating astronomical mirrors with a layer of metallic aluminum deposited thereon by evaporation in vacuo."

The Franklin Medal, awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., "to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications," was awarded to Edwin Hubble, Ph.D., D.Sc., LL.D., Mount Wilson Observatory, Carnegie Institution of Washington, Pasadena, California, "In recognition of his extensive study

of the nebulae, particularly those outside our galaxy, as a result of which the dimensions of observed space have been greatly increased."

Following the presentation of the awards Dr. Hubble read an original paper on "The Motion of the Stellar System Among the Nebulae."

Book Reviews

Tables of Addition and Subtraction Logarithms, by D. B. Cohn. (Scientific Computing Service Limited, 23 Bedford Square, London, England. 10/-.)

The first edition of this work was published in Leipzig in 1909. This edition was exhausted, and those interested in the aids to computational problems felt that a new edition was needed. The original publisher, not wishing to issue a second edition, gave permission to the re-publishing of the volume in England.

The book, well bound in cloth, consists principally of 63 pages of the tables (six-place decimals) mentioned in the title. It contains also a preface, in German, to the first edition and one, in English, to the second edition.

Although computing machines have made logarithms unnecessary in much of the numerical work that is now being done, nevertheless there are times when logarithms are very useful. In such cases it is well to have the usual tables of logarithms supplemented by addition and subtraction logarithms which this book furnishes. This volume, therefore, or one similar to it, deserves a place in any institution in which computations play an important part in its activities.

Variable Stars, by Cecilia Payne-Gaposchkin and Sergei Gaposchkin. (Harvard Observatory, Cambridge, Mass. 361 pp. $3.25. 1938.)

This volume by Mrs. Gaposchkin and her husband is No. 5 of a series of monographs which is being published by the Harvard Observatory. It is not a textbook but a handbook of the subject. The classification adopted is Geometric variables, Intrinsic variables, Cataclysmic variables, and Extrinsic variables.

As an illustration of the methods of exposition we shall take the geometric variables or eclipsing binaries. These are discussed under the following headings: Rotation of Eclipsing Stars to Other Fields, Discovery of Eclipsing Stars, Definitions, Physical Groups, The Relative Numbers, Periods, Magnitudes, Amplitudes, Eclipses, Spectra, Radii, Masses, Densities, Temperatures, Radial Velocities, Galactic Distribution, Eclipsing Systems as Standards for Theoretical Problems, and The Additional Effects. Under this last heading are considered ellipticity of components, eccentricity, apsidal motion and libration, rotation effect, reflection effect, darkening at the limb and the Tikhoff-Nordmann effect. There are included 25 references to sources, many footnotes, a number of tables, a catalogue of the relative elements of 268 eclipsing systems, and finally nine pages of description of the more important eclipsing systems. The other classes of variables are dealt with in the same manner.

The index of 20 pages is a list of the stars, approximately 1600 in number, referred to in the text.

This book represents a tremendous amount of work. It should be in the hands of all observers of variable stars as well as in every astronomical library. E.A.F.

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